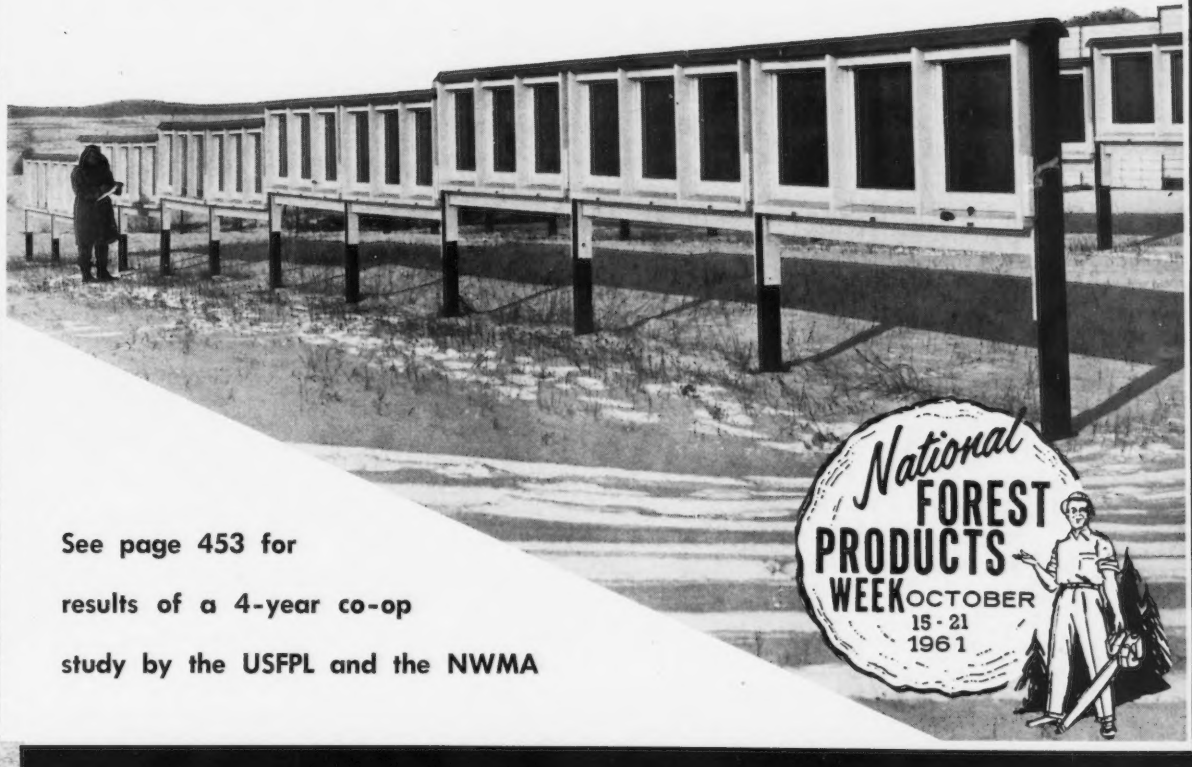
FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY

How do lab tests compare with weathering tests of water-repellent preservatives?



See page 453 for results of a 4-year co-op study by the USFPL and the NWMA

Vol. XI, No. 10

1961 / OCTOBER

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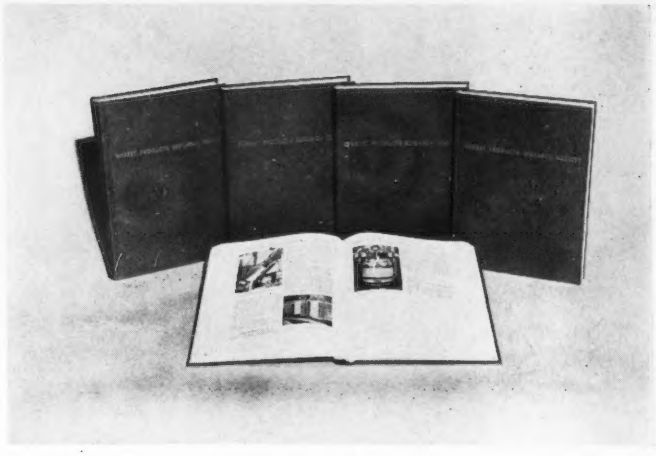

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1947—Vol. 1—UTILIZATION, ENGINEERING, PRESERVATION, SEASONING. 25 papers, 344 pp.

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1948—Vol. II—UTILIZATION, FIBER PRODUCTS, BARKING, FINISHES, MACHINERY, R. F. HEATING. 50 papers, 500 pp.

Articles cover: economics of wood-waste utilization; losses in Redwood logging; small log gang sawmill; utilization of low-grade hardwood lumber; wood-distillation industry; sawdust carbonization; animal feeds from wood residue; small wood briquetting machine; special machines for utilization of waste slabs for glued core stock; interior trim from wood waste; wood-fiber production with revolving disk mills; effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-Fir; small hydraulic log barker; mechanical methods of bark removal; studies on the chemical composition of bark and its utilization for structural boards; research in industry laboratories; history of furniture finishes; finishes resistant to alcohols and acids; low-bake synthetic finishes; simple testing methods for finishers; planning floor space for woodworking equipment; maintenance and operating practice for tungsten carbide tools.

1949—Vol. III—RAW MATERIAL, FURNITURE, PLYWOOD, UTILIZATION, GLUES, SEASONING. 55 papers, 607 pp.

Articles cover: more wood per acre; integrated wood utilization at Crossett; harvesting sawlogs; portable wood chippers; wood fibers from veneer waste; small permanent-type sawmills in better forest utilizatiton; pulpwood handling in the Lake States; tropical wood research for the furniture industry; effect of plywood glue lines on the accuracy of moisture-meter indications; No. 3 common Northern hardwood lumber for mechanized processing into glued products; cut stock from western softwoods; assembly material in furniture manufacture; supplementing wood with metal in furniture manufacturing; extending hot press urea resin with wheat and rye flour; furniture finishes; lumber core panels; rotary veneer cutting; molding plywood; insert-point circular headsaws; ills besetting the furniture industry; utilization of Redwood bark; utilization of waste sulfite liquor in concrete; semichemical pulping; dry-formed boards bonded with resins; wood, plywood and hardboard; compreg-resin-treated densified wood; wood preservatives; wood boring beetles; ignition temperatures of fireproofed wood, untreated sound wood, and untreated decayed wood; wood waste disposal and air pollution control in the Los Angeles area; pulp mill pollution; chemical composition of Ponderosa and Sugar Pine barks; lumber recovery from Douglas-Fir logs in British Columbia; resin adhesives; development of working stresses for stress-grade lumber; design and performance of laminated wood trusses, glued laminated wood, glued laminated Wej-weld frames; radio frequency heating.

1950—Vol. IV—MILLING, CONTAINERS, QUALITY CONTROL, PLYWOOD. 45 papers, 506 pp.

Articles cover: quality of second growth Douglas Fir; grading problems; quality control and the improved seasoning processes of the Redwood industry; saw teeth in action; lumber research to meet modern competition; hardwood log grading; recent developments in wirebound containers; method of utilizing and fabricating waste lumber; tests of strapped and lightweight lettuce crates; recent developments in containers; papermaking fibrous raw materials; utilization of low-grade hardwoods and softwoods; relation between wood and pulp properties; power vs. hand falling and bucking in logging operations; handling pulpwood; quality control in sawmill operations; hardwood plywood quality control; quality control in furniture production; defect detection equipment non-destructive testing.

1951—Vol. V—MILLING, MACHINING, PRESERVATION, UTILIZATION, GLUES, KILN DRYING. 51 papers, 400 pp.

Articles cover: circular sawmills in the Tennessee Valley region; quality control in lumber manufacture, gangsaws in the manufacture of southern pine lumber; tropical hardwood production, logging and military equipment availability; defense and the availability of woodworking equipment; the importance of wood in the mobilization program; mobilization requirements for technical men in the woodworking industry; lumber conservation in military procurement and container design; military requirements for wood in packaging; wood requirements for specialized military uses; the place of small business in the military procurement program; marine laminating; selecting White Oak for bending lumber; machinability studies; carbide cutting tools in the wood industry; carbides; fire retardant treated lumber; wood preservation with particular reference to creosote; what the furniture industry expects from college-trained men; the scope and objectives of college training; graduate training in forest products technology.

FOREST PRODUCTS JOURNAL

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WATCH FOR THESE NOVEMBER FEATURES

A major advance in the wood-preservation industry
Report on a new process for separating bark from chips
A comprehensive analysis of high-temperature drying
Architecture of cellulose . . . "One of the better papers in the history of FPRS"

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. . . from the President's Desk

THE WEEK OF OCTOBER 15 has been designated Forest Products Week, now being observed for the second year. By such media as special news features, store window displays, plant open-house visits, and other demonstrations, agencies concerned with forest products will call public attention to the important part wood plays in the national economy.

Undoubtedly and appropriately, the uniqueness of the forests as a renewable resource will be pointed out. Sponsors of Forest Products Week can also boast that the forest products industries began with the earliest settlements. They should emphasize that earlier management practices and attitudes toward utilization, however applicable for their time, generally have given way to others that we now consider more enlightened.

Almost anyone can cut a tree, and it takes little to set up a mill to convert it to lumber, or to go into the business of processing it further in construction or some kind of manufacturing. The logical result of these conditions is an industry of small units, whose founders may have shown considerable initiative, aggressiveness, and willingness for risk. If they have prospered, their successors often ignore changing circumstances, and they adhere to the founders' patterns, their main objective being to conserve what they have. This is the "grandpappyitis" Bob Dosker so vividly described at this year's National Meeting in Louisville.

The forest of today is not the forest that stood in the same spot only a few years ago, nor will that forest stand there a few years hence. The best techniques for harvesting, processing, and marketing forest products are not necessarily those same techniques which were used in the past. Nor will those of today necessarily remain the best in the future.

It is at this point that the Forest Products Research Society fits into Forest Products Week, with an obligation to show not only the general public, but more important, the forest products industries, how best to adapt their techniques to changing times. We must foster research in forest products, and apply the results of that research.

By keeping our eyes on the "new" rather than the "old," by the vigorous encouragement and application of research, our industry will provide the public with quality products—suitable justification for the observance of a Forest Products Week.

Donald K. Saunders

Inland Empire to Meet Oct. 26–27

The next meeting of the Inland Empire Section of FPRS will be at Washington State University, Pullman, Washington, on October 26 and 27. The theme will be varied as there has been an indication from the membership that subject interest has been diversified.

The speakers and titles of subjects are as follows. The keynote address will be by Dr. John A. Guthrie, Director of the Bureau of Economic and Business Research, Washington State University. Dr. Guthrie's subject will be "The Development of the Forest Products Industries of the West." John A. Haase, sales representative, Boise Cascade Kraft Corporation will speak on "The Influx of Paper Usage in the Lumber Industry." The next paper will be on the subject of "Laminated Beams from Common Grades of Lumber." This will be co-authored by Merl C. Filler, John Howe, and Arland Hofstrand. Joseph J. Allegretti, Director of Special Products for the Scott Lumber Company Corporated at Burney, California, will report on the "Activities of FPRS National Committee on Bark Mulch Standardization."

T. S. Veazey of the Anaconda Company at Bonner, Montana, and president-elect of FPRS will present the plans for the national meeting to be held in Spokane, Washington, in 1962. A tour will be made of the physical properties of the Wood Products Research Laboratory at the Washington State University, Pullman, Washington.

Southern Wood Exposition to Highlight Mid-South Meeting

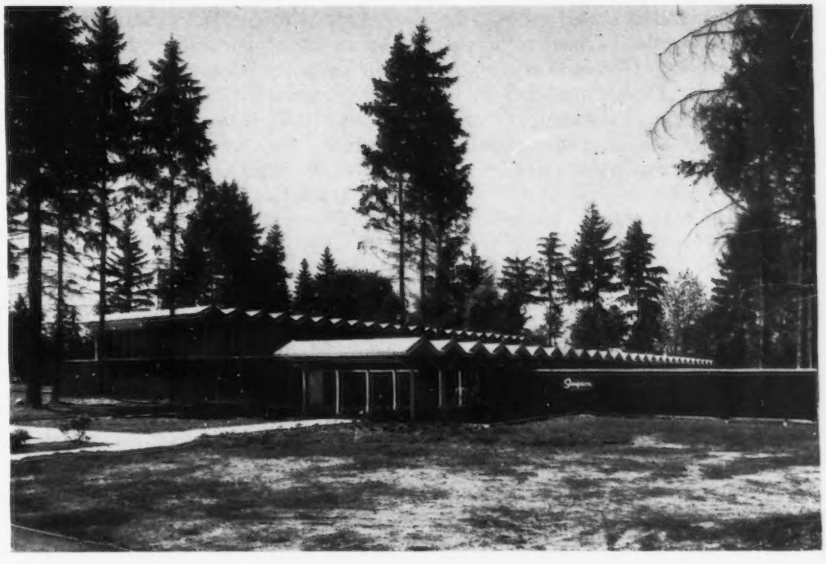
The Mid-South Section meeting and the Southern Wood Exposition, scheduled for October 11–13 in Jackson, Miss., are expected to attract several thousand spectators and registrants.

Manufacturers from all over the country have been invited to attend the event and to inspect the new wood products ideas that have been submitted by contestants in the National Contest sponsored by the Mid-South and the Exposition.

Aubrey Henson, executive vice president of the Mississippi Industrial Land and Timber Corporation, is general chairman of the Exposition, and James Craig, president of Forestry Suppliers, Inc., is chairman of the New Wood Products Contest.

FPRS News-Digest

Simpson Timber Opens Research Center



Simpson Research Center features folded roof plates and diamond box beam roof construction. Offices and laboratories open on attractive garden-type courtyards.

Simpson Timber Company formally dedicated its new Research Center on August 16, in conjunction with the NAHB meetings in Seattle. Principal speaker during the ceremonies was E. J. (Jim) Burke, Jr., president of the NAHB.

The Research Center, situated on a 10-acre wooded site in the new Overlake Industrial Park near Bellevue, Washington, 12 miles east of Seattle, is a progressive statement of the beauty, utility and integrity of wood.

Created by Paul Hayden Kirk, F.A.I.A., distinguished Seattle architect, the building features such architectural components as glued laminated columns, folded roof plates, selected plywoods, and a diamond box beam roof construction, unique in industrial design.

Kirk's artistic perception and his technical mastery of wood as a building material have been skillfully blended to produce an interesting, practical and inspiring workshop.

The Research Center marks the second major building project completed this year by Simpson. An ultra-modern sawmill at Shelton, Washington, also featuring wood construction, was opened in February.

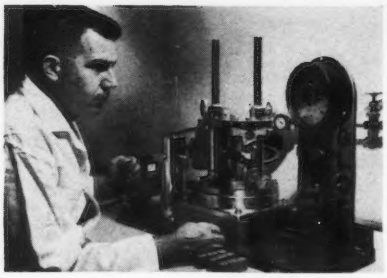
Six months in the planning stage and eight months in construction, the new Simpson facility comprises 22,000 square feet of floor space housing, in addition to the administration area, nine forest product research and development laboratories, a large pilot plant, and a library which will become a technical information center for the entire company.

The Center has emerged as a showplace for Simpson building products, a pleasant and functional work area, and a reaffirmation of Simpson's belief in the future of wood and the creativity of its people.

William G. Reed, Simpson Chairman, described the Center as "achieving a new goal in our company's objectives of supplying wood products for the nation through sustained yield forest management and total utilization of trees."

The Research Center building houses two principal activities: the Research Division, under the direction of Robert

Coatings section in new center. Floor plan was designed so that each section forms a cohesive unit consisting of section chief office, laboratory, and pilot plant.



Adhesives research is one phase of operations at the new center. Here, a technician performs gluebond tests on plywood samples.

J. Seidl, general manager of the Research and Chemicals Department; and the Engineering Division, under the Manufacturing Department, headed by Byrne C. Manson, director of engineering. Seidl also is responsible for the general administration of the Center.

The laboratory is staffed and equipped to conduct experiments on a broad scope of forest products of present or potential interest. It will service Simpson operations throughout Washington, Oregon and California and its location in Overlake Park places it within easy access of convenient transportation centers and the Simpson central offices in Seattle.

Wood Composition Board Clinic Sponsored by Midwest Section

The annual meeting of FPRS Midwest Section, which will be held in Chicago's fabulous McCormick Place, October 19–20, will feature a "Wood Composition Board Clinic" for both producers and users of all types of composition board.

James C. Elf, National Starch and Chemical Corp., who is general chairman of the meeting, predicts a registration of more than 200.

"We've planned the Clinic around two panels and an open forum or question and answer period, and we have topnotch men covering each phase of the work," said Elf.

Thursday morning will be devoted to a "producer panel" on insulation boards, hardboards, and both flake- and shaving-type particleboard. The afternoon sessions will be devoted to a "user panel." The panel will be manned by technicians and executives representing concerns using composition boards in prefabricated houses, institutional and laboratory furniture, millwork and kitchen cabinets, laminated panels, musical instruments, household furniture, and mobile homes. A special session will be held on finishing problems.

Friday, October 20, will consist of an Open Forum on Wood Composition Boards. The question and answer period will be open to all members of the audience and the panels.

Registration for the 2-day program is $5.00 The Official Luncheon, with H. C. Smith, Director of Marketing, Braun & Aldridge, Inc., as guest speaker, will be $4.00.

The Midwest Section will hold its annual business meeting Thursday afternoon at the conclusion of the technical panel. Section Chairman Willard Gullicksen will preside.

Instrumentation Featured at Pacific NW Meeting

The annual fall meeting of the Pacific Northwest Section of FPRS, which will be held at Qualicum Beach, Vancouver Island, B. C., October 16–17, will feature a special panel session on instrumentation.

The instrumentation phase of the PNW program will be conducted under the auspices of the Instrument Society of America. It will be coordinated by James Dallas, Plywood Research Foundation, and chairman of the ISA Committee on Wood Products. Panel speakers have not been named.

Speakers for the second technical session will include: Dr. Harvey Erickson, University of Washington, on permeability of Douglas-fir; J. C. Clapham, British Columbia Research Council, on economics of automatic sorting; Dr. Murray Carroll, Borden Co., on resin efficiency in particle board; and Harry Berry, Douglas Fir Plywood Association, on analysis of new product development.

The official banquet speaker will be Bob Smith, editor of Crow's Lumber Digest. The meeting will conclude with tours of the Comox Logging operation and the Elk Falls pulp and lumber operations of Crown Zellerbach, Canada, Ltd.

Northern California Will Meet Oct. 20 at Fort Bragg, Calif.

"Utilization of Young Growth" will be the theme of the Northern California Section's annual fall meeting scheduled for October 20 in Fort Bragg, Calif.

Dr. R. L. Youngs, U. S. Forest Products Laboratory, will discuss the comparative wood and fiber properties of young and old growth material; William Smith, J. H. Baxter & Co., Willits, Calif., will describe the potential of young growth for round wood utilization; Robert Grundman, Union Lumber Co., Fort Bragg, will discuss problems of young growth utilization; and Dr. Herbert McKean, Potlatch Forests, Inc., Lewiston, Idaho, will discuss modern trends in product development.

Harold P. Plummer, vice president in charge of production, Union Lumber Co., will be the featured speaker at the official noon luncheon. The program will conclude with a tour of the Union Lumber Company plant.

Carolinas-Chesapeake Section To Hold Annual Meeting Nov. 2

"Methods for Extending the Use of Wood and Wood Products" will be the theme of the Carolinas-Chesapeake Annual Meeting Nov. 2–3 at the Battery Park Hotel in Asheville, N. C.

Three technical sessions are planned on wood preservation, wood stabilization, and gluing. Speakers will be: J. Kowal, Southeastern Forest Experiment Station; H. Mitchell and R. H. Baechler, U. S. Forest Products Laboratory; I. S. Goldstein, Koppers Co.; A. J. Stamm, C. A.. Hart, and J. T. Rice, North Carolina State College; C. Skaar, Syracuse University, and Paul Zottu, Industron Corp. R. J. Thomas, School of Forestry, North Carolina State College, is program chairman.

Eastern Canadian to Hold Third Regional Meet

Plans are being developed for the Third Regional Meeting to be held in Quebec City by the Eastern Canadian Section on October 16th. Dr. Joseph Risi, Professor of Wood Chemistry, Faculty of Science, Laval University is the chairman. The majority of the papers will be given in French.

Two very successful meetings were held earlier this year at Pembroke and Kitchener, Ontario, and it is anticipated that the Quebec meeting will attract good attendance.

NEW OR TRANSFER MEMBERS IN SEPTEMBER

Section Officers please note. Each month we will publish the new or transferred-into-the Section members for the previous complete month. New members are listed in boldface type, transfers in regular type. Letters in parentheses after the members name indicate: (A), associate; (V), voting; (s), student; and (S), supporting.

CAROLINAS–CHESAPEAKE

Jesse D. Wellons, (s) 1021 Gloria Ave., Durham, North Carolina

Pvt. Thomas J. Albert (s), FR 19680458, Hg. Co., CRDL, Army Chemical Center, Maryland

W. A. Campbell (V), Box 208, Chapel Hill, North Carolina

Ronald Jokerst (V), 615 Green Street, Durham, North Carolina

Abdus Samad (A), P. O. Box 5457, State College Sta., Raleigh, North Carolina

EASTERN CANADIAN

E. S. Little (V), Jamar Plywood Limited, P. O. Box 454, Kirkland Lake, Ontario, Canada

Kenneth R. MacLean (V), Guelph Plywood Co., Mattawa, Ontario, Canada

GREAT LAKES

Richard N. Jorgensen (V), Extension Specialist in Forest Products, Michigan State Univ., East Lansing, Michigan

Joe LaSpisa (V), 69 Pacemaker Plaza, Brewster Court, Toronto, Ohio

T. Walter Noble (V), Fabricon Products, 1721 Pleasant Ave., River Rouge 18, Michigan

C. Curtis Peterson (c), 1013 Hamilton Ave., Fort Wayne, Indiana

INLAND EMPIRE

William W. Gleaves (V), 1923 N. Broadway, North Bend, Oregon

Melvin D. Strickler (V), Washington State Institute of Technology, Pullman, Washington

MID-SOUTH

James R. Pettey (V), Warren A. Hood Forest Products, P. O. Box 8592, Jackson, Miss.

M. Pick (V), Pascagoula Veneer Co., P. O. Box 612, Pascagoula, Miss.

J. R. Savage (V), Meridian Woodworking Co., P. O. Box 4007, Meridian, Miss.

L. V. Witt (V), E. L. Bruce Co., Columbus, Miss.

MIDWEST

Md. Abdur Razzaque (A), Forest Products Laboratory, Madison 5, Wisconsin

Samuel D. Bixler (s), R. F. D. #1, Corning, Iowa

Henry Hinterkopf (V), 1808 Third Street, Peru, Illinois

Jack E. Kepler (s), R. R. 2, Emerald Court, Ames, Iowa

John A. Pence (V), 3225 St. Francis Drive, Springfield, Illinois

NORTHERN CALIFORNIA

Larry R. Artman (V), Scott Lumber Company, P. O. Box 42, Burney, California

Donald G. Ball (s), 422 44th Ave., San Francisco 21, California

Dr. L. W. Crandall (V), United Nations, % U. S. Embassy, APO 928, Postmaster, San Francisco, California

William J. McCudden (V), P. O. Box 4962, Carmel, California

NORTHEAST

James F. Pfanstiel (V), National Lumber Mfrs. Assn., 345 Mt. Lebanon Blvd., Pittsburgh, Penn. (34)

Ross R. Williams (V), Norfolk Products Corporation, Norfolk, Conn.

R. L. Bremhorst (V), 66 Hillap Ave., Springdale, Conn.

W. K. Grubman (V), 972 Kensington Ave., Plainfield, New Jersey

Ronald W. Haigh (s), 301 Prospect St., New Haven 11, Conn.

Albert L. Price (s), 91 So. Main St., Moravia, New York

Alfred Schainholz (V), 144 West Fourth Street, Bloomsburg, Pa.

F. H. Vogel (V), Amcongen–ICA, APO 380, New York, N. Y.

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Mel W. Balgemann (V), Borden Chemical Co., 1735 Lilly Lane, New Albany, Indiana

Harold Rose (V), Reliance Varnish Co., 4730 Crittenden Dr., Louisville 9, Kentucky

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B. R. Lewis (V), % Omark Industries, Inc., 9701 McLoughlin Blvd., Portland, Oregon

Philip J. Sedlacek (A), 138 N. E. 52nd Street, Seattle 5, Washington

PACIFIC SOUTHWEST

William J. Kidd (s), 1362 Rodeo Drive, LaJolla, California

SOUTHEASTERN

Louis I. Gaby (s), School of Forestry, Univ. of Georgia, Athens, Georgia

FPRS SECTION MEMBERSHIP GOALS

Wanted: 331 New Members by June 1, 1962

Section	New V. & A. Members Section Goal	Percent of Goal Attained	Goal for New Supporting Members	Percent of Goal Attained
Midwest	30	10	3	0
Ohio Valley	10	40	2	0
Great Lakes	20	5	1	0
Upper Mississippi Valley	10	10	1	0
Mid-South	25	28	3	33
Northeast	45	9	5	0
Eastern Canadian	20	10	2	0
Carolinas–Chesapeake	30	3	3	0
Southeastern	10	0	1	0
Pacific Northwest	50	6	5	0
Inland Empire	10	0	1	0
Northern California	20	5	2	0
Rocky Mountain	10	0	1	0
Pacific Southwest	10	10	1	0
Total	300		31	

Membership Chairmen are: Midwest, R. C. Newstedt; Ohio Valley, W. C. Seng; Great Lakes, N. C. Franz; Upper Mississippi Valley, S. H. Wise; Mid-South, H. L. Russell; Northeast, P. H. McCormack; Eastern Canadian, A. E. Glennie; Carolinas–Chesapeake, Sam Freeman; Southeastern, P. J. Bois; Pacific Northwest, Tom McKenna; Inland Empire, R. W. Bruce; Northern California, Collins Orton; Rocky Mountain, R. S. Bader; Pacific Southwest, W. E. Ripley, Jr. *Help Your Membership Chairman Meet His Quota!*

Memorial Wood Collection

Prof. Harold A. Core, left, and Dr. Carl H. de Zeeuw, both members of the faculty of the Department of Wood Products Engineering at the State University College of Forestry, examine a rare specimen of wood recently added to The Harry Philip Brown Memorial Wood Collection. Several hundred wood samples are added to the collection each year. The collection, composed of close to 20,000 different wood specimens, is housed in the Department of Wood Products Engineering, on the fourth floor of the new Hugh P. Baker Memorial Wood Products Laboratory building, on the main campus of the Syracuse Forestry College, Syracuse, N. Y.

University of Wisconsin Plans Conference on Wood Poles

The University of Wisconsin will hold an Engineering Institute on Wood Utility Poles in Madison, November 14 and 15, with emphasis on preservation, inspection and quality control, and maintenance.

John Peterson, Institute Coordinator, has invited a panel of nationally recognized experts to handle the various phases of the two-day meeting.

The conference objectives will be established Tuesday morning by John H. Rixie, Jr., of the Rural Electrification Administration. He will be followed by three speakers from the U. S. Forest Products Laboratory—Lyman W. Wood on pole quality and ASA specifications; Ralph M. Lindgren on deterioration of poles; and B. Francis Kukachka on the relation of anatomical characteristics of wood to preservative treatment.

Tuesday afternoon will be devoted to discussions of the production of quality poles. Pressure treatment will be covered by D. L. Davies, Koppers Company, Inc.; thermal treatment will be discussed by J. E. Eastman, Valentine Clark Corp.; and inspection and quality control will be handled by W. Roy Yeager, Western Electric Company, Inc. The sessions will conclude with a discussion of preservative analysis by R. H. Baechler, U. S. Forest Products Laboratory.

Pole service and maintenance problems will be discussed Wednesday morning. Speakers will include: G. Q. Lumsden, Bell Telephone Laboratories, Inc.; F. P. Tierney, Northern States Power Company; W. J. O'Neal, REA Electric Engineering Division; and A. H. Hearn, American Telephone & Telegraph Co.

The afternoon sessions will include an evaluation of groundline treatments by J. Oscar Blew of the U. S. Forest Products Laboratory and a discussion of pole-line economics by R. H. Colley, Bernuth Lembke Co., Inc. The meeting will conclude with a summary presentation by Frank Linder, Dairyland Power Cooperative.

Additional information may be obtained from: John Peterson, Institute Coordinator, Extension Division, Department of Engineering, University of Wisconsin, Madison 6, Wis.

Georgia-Pacific Contracts With National Bagasse

A major contract has been concluded between National Bagasse Products Corporation and Georgia-Pacific Corporation for the sale and distribution of National's new sugar cane bagasse hardboard and woodworking board materials. Details of the contract were given by Haigh Reiniger, vice president and head of sales of National Bagasse. At the same time, it was disclosed that a substantial share of the company's production will be distributed through a network of more than 100 wholesale warehouse points throughout the United States. Construction of the National Bagasse factory is underway at Vacherie, Louisiana, and the start-up of the plant is scheduled for early in 1962.

National Bagasse will introduce the sugar cane fiber as a new source of basic raw material in board products for the plywood, furniture, fixture, building construction, and a large number of industrial fabricating industries formerly having access only to wood as the essential material in similar board products. National Bagasse boards can be nailed, stapled, drilled, and machined with ordinary woodworking tools and they provide perfect surfaces for veneering with wood, metal, and plastics. The process creates entirely new uses for the sugar cane fiber, which remains after extraction of sugar and was formerly wasted or burned for fuel.

New Laboratory For Lake States

Funds for a new U. S. Forest Service forest research laboratory in St. Paul, Minn., have been approved by Congress, according to M. B. Dickerman, Director of the Lake States Forest Experiment Station. Congress appropriated $1,250,000 for development of the site, construction of the laboratory, and installation of laboratory fixtures and specialized equipment.

According to Director Dickerman, "This new modern building will be located on the St. Paul Campus of the University of Minnesota just north of the present Forestry School. This location will facilitate the excellent cooperative working relations we have had for 38 years with the University of Minnesota. We are gratified that the Board of Regents of the University has made this site available." Since it was organized in 1923, the Station has been located in space provided by the University. Plans for the new laboratory are underway and construction should start in 1962.

Wooden Pallet Clinic

As part of its college-service-to-industry program, the State University College of Forestry at Syracuse University, Syracuse, N. Y., in cooperation with the National Wooden Pallet Manufacturers Association, Washington, D. C., will sponsor the 5th Annual Clinic on wooden pallet manufacturing and sales to be held November 1 and 2, 1961, at the Hugh P. Baker Forest Products Laboratory at the College of Forestry.

Commenting on the forthcoming course, William H. Sardo, Jr., Executive Vice President of the National Wooden Pallet Manufacturers Association said: "The Clinic affords those connected with the wooden pallet industry a once-a-year opportunity to exchange the best ideas on manufacturing and merchandising pallets, and to study the newest techniques. The 1961 sessions are particularly timely in that this industry is on the verge of a major expansion of its markets."

The two-fold purpose of the course is to familiarize those enrolled with good fabrication, marketing, and management techniques used in the manufacturing of wooden pallets and to present the latest authoritative information on the overall industry problems so that the obstacles to a wholesome expansion of the wooden pallet industry may be eliminated. To register or to obtain further information, write or telephone Russell C. Deckert, State University College of Forestry at Syracuse University, Syracuse 10, New York.

GRAND RAPIDS—(l. to r.) Theodore V. Burba, plant superintendent, John Widdicomb Co., and Dr. Stephen B. Preston, head of the University of Michigan's Department of Wood Technology, check schedule for Wood Technology meetings.

Grand Rapids Furniture Technology Topics Set

The agenda for this fall and winter's Furniture Technology meetings in Grand Rapids will dwell heavily upon wood finishing and gluing techniques, according to F. W. Dunn, managing director of the Grand Rapids FMA. The Furniture Technology meetings, a continuing program offered jointly by the Furniture Manufacturers Association of Grand Rapids and the University of Michigan's Extension Service and Department of Wood Technology, are dedicated to the producing of better furniture through application of wood science and technology, according to Dunn. The meetings bring together technical management of the Grand Rapids furniture industry with experts from the University's Wood Technology Department.

The FMA's Education and Research Committee, under the chairmanship of Theodore V. Burba, plant superintendent of the John Widdicomb Co., met recently with Dr. Stephen B. Preston, head of the U of M's Wood Technology Department and Dr. Norman Franz, a professor in the department. The following schedule for the fall and winter sessions grew out of the meeting:

1) Coated Abrasives and Sanding (Introduction): Types of abrasive materials will be discussed, as will machining with abrasives. Dr. Franz will lead the discussion.

2) Finishing Materials: A summary of important finishing materials and systems. G. P. Bruneau, Wood Technology Laboratory Supervisor will be in charge.

3) The Sanding and Finishing Process (Advanced): A panel discussion moderated by Dr. Franz on current processes of sanding and finishing in the furniture industry.

4) The State of Knowledge of Wood Adhesives: This session will be a summary of proceedings of the national conference on adhesion held in Ann Arbor during the summer of 1961. A. A. Marra, Professor of Wood Technology at the University of Michigan will officiate.

5) The Use of High Frequency in Assembly Gluing: This session will be headed by Dr. Marra.

6) Selection and Purchasing of Raw Materials: This session will include the use of dimension stock in furniture manufacture. It will be headed by Dr. E. L. Ellis, Associate Professor of Wood Technology at the University of Michigan.

U.S. FPL Head Attends Forest Research Conference in Vienna

Dr. Edward G. Locke, director of the U. S. Forest Products Laboratory, attended the 13th Congress of the International Union of Forest Research Organizations held in Vienna September 10–18.

He also visited various research institutes and laboratories and commercial plants in the forest products field in England, France, Germany, Belgium, Sweden, Norway, and Finland both enroute and upon his return trip from Vienna to obtain first-hand knowledge of current activities abroad as a basis for better evaluation of programs presently being carried on at the Laboratory.

In Rome, Dr. Locke met with officials of the Food and Agriculture Organization of the United Nations to discuss the possibility of the Laboratory being host to the 5th International Wood Technology Congress that will be held in 1963.

At the Vienna Congress, Dr. Locke proposed that this international body expand its program so that research on wood utilization is given equal emphasis with research on forest management and silviculture.

"We feel that product research programs should not be divided from those devoted to forest management and silviculture. All wood research programs should be co-ordinated," Dr. Locke explained.

He pointed out that the concept of targeting research to provide knowledge to make more effective use of our timber resources had won worldwide recognition of leadership in forest research for the Laboratory here.

It will be up to us in the United States to provide the leadership and a strong effort will be needed from wood utilization research workers in Europe as well as the United States if a balanced program in this international organization is to be achieved, Dr. Locke said.

Ohio Valley Meeting Will Feature Merchandising

A panel discussion on "Merchandising Lumber Products" will be one of the highlights of the annual fall meeting of the Ohio Valley Section of FPRS, which is scheduled for October 12–13 in Jeffersonville, Indiana.

The two-day meeting will also include a presentation on "Trends in the Wood Industry," by representatives of the Department of Economic Research, University of Indiana, and an evening "I've got a problem session," at which specific problems will be solved by a panel of experts.

The meeting will conclude Friday morning with a discussion of the research and public services available through the Kentucky Department of Economic Development and the Spindletop Research Laboratory.

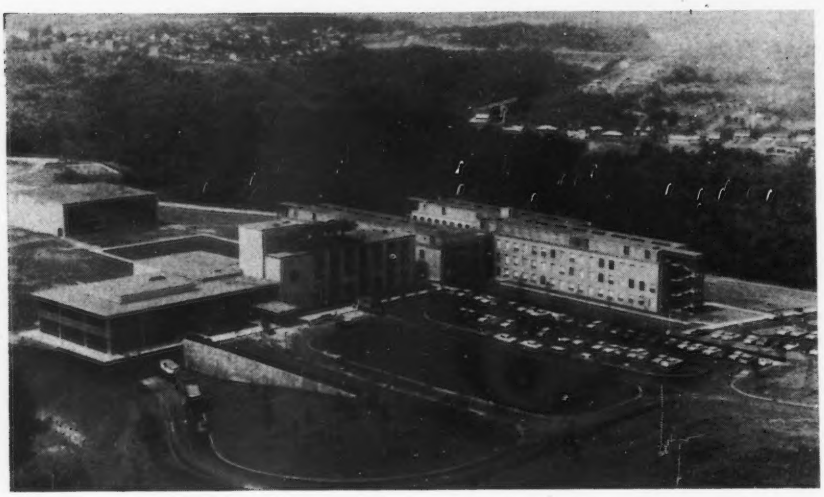
FPL Identification Expert Studies Hawaiian Timbers

Ways of making better use of the forests of Hawaii—now dependent on imports for most of its timber—were investigated by B. F. Kukachka, wood identification expert at the the U. S. Forest Products Laboratory, Madison, Wis., on a three-week trip to the Nation's newest State during August and September.

While in Honolulu, Dr. Kukachka addressed the Tenth Pacific Science Congress on scientific methods he uses in helping settle criminal investigations, business disagreements, and other cases hinging on wood identification. He has developed new procedures for identifying woods grown in all parts of the world.

The well-known wood expert conferred with Hawaiian forestry officials and industry leaders on possibilities of expanding the utilization of that State's forests. Of the 500 species exotic to Hawaii, many are too heavy or too light for furniture, building construction, and other ordinary uses, he says. Many also contain silica, a tool-dulling mineral that holds back their use. Dr. Kukachka visited timber plantations on Oahu and Hawaii to consult on suitability of various species for standard or specialty uses.

Koppers Dedicates New Research Center



Aerial view of Koppers Research Center in Somervell Park, Monroeville, Pa. This first stage of the center will house 450 scientists and their assistants. When the 176-acre Center is completed it will accomodate 1500 people.

Koppers newest and largest research facility, at Somervell Park, Monroeville, Pa., was dedicated on August 28. It represents an investment of approximately eight and one-half million dollars according to Fred C. Foy, Chairman of the Board.

"This Research Center provides uniquely suitable facilities for Koppers scientists whose role in our corporate growth is critically important. It does more than symbolize our faith in the future; it is now, and will become more so, the keystone of our total research effort," said Foy.

Koppers Company, Inc. a 49-year-old Company with annual sales in excess of 300 million dollars, began to accelerate its research program about fifteen years ago when it moved into chemicals and plastics. Until that time the Company had been largely identified with engineering and construction —mostly in the steel industry; coal by-products, wood preserving, fabricated metal products and merchant coke plants.

The Center itself consists of a 5-story administration building, three 3-story interconnecting laboratory wings and several outlying auxiliary buildings. A feature of the Center which contributes to its easy expansibility is the glass enclosed stairways at the end of each wing which can be easily removed when additions are called for, and reaffixed to the end of the new wing.

Foy cited this "planned expansibility" of the Center as indicative of the Company's long-term commitment to research.

Only about one-third of the buildings planned for the 176 acre site have been completed. According to Dr. Paul W. Bachman, Koppers Vice President and Director of Research, the Center will eventually be able to house over 1,500 scientists and their assistants—about four times its present population.

At the dedication ceremony, Mrs. Brehon Somervell, widow of the late Commanding General of the Army Service Forces, unveiled a bust of her husband who was Chairman of the Board and President of Koppers until his death in 1955.

Mr. Foy recalled a statement that General Somervell made in 1953 on the subject of research:

"Industry looks forward to the future and not backward to the past. And this dream constantly is being given substance through the vast scientific effort represented by industry's research. The inexorable march toward new scientific horizons is of immeasurable value to our society."

Citing a few Koppers research and development accomplishments, Foy mentioned: Dylite expandable polystyrene, a foam plastic introduced to this country by Koppers; Non-Com fire retardant wood products; many contributions to increased efficiency in steelmaking; and a new line of polyepoxide resins, known as Ker epoxy resins.

Foy also mentioned the work Koppers is doing in boron chemistry, plastics, fiber reactive dyes, and chemical intermediates. He also described a non-precipitating dye that imparts permanent coloring to anodized aluminum.

One research project that Koppers believes has great promise involves the desalinization of sea water. Known as Koppers Hydrate Process—now in bench scale operation—it is the only chemical approach to this problem that is under serious investigation, according to Dr. Bachman, who cited the importance of the problem in these terms:

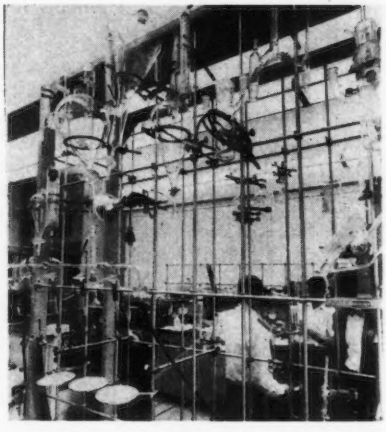
"Between now and 1975 the daily water needs in the United States will rise from 312 to 450 billion gallons a day. This will mean a very real scarcity of potable water in many localities. One obvious solution is an economically feasible process of removing salt from sea water—a supply amounting to the incredible figure of 320 million cubic miles."

It is expected that this project which is being carried forward in cooperation with the Department of the Interior, will soon move into pilot plant production of 10–15 thousand gallons per day.

Besides Somervell Park, Koppers operates eight other research and development facilities of varying sizes where product and process control, application research, and pilot plant operations are the principal activities.

At Monroeville, in addition to all new product research, the Exploratory Section of the central research staff will work in areas wholly new to Koppers where, as Foy puts it:

"The only limitations on the scientists' imagination is that there exists some presumption of meaningful results, some expectation of profitable end products."



Chemists, physicists, and other professional employees at Koppers new research center have been furnished the most modern facilities.

Weyerhaeuser Uses Helicopter In Forest Rehabilitation

Each year almost 25,000 acres of forest lands in western Washington and Oregon are rehabilitated by helicopter spraying and seeding, according to a report recently released by Evergreen Helicopters, charter operator supplying year-long contract service for Weyerhaeuser Company's continuing forest rehabilitation program.

During peak periods, the operation keeps two 305-horsepower Hiller 12E's in the air up to 6 hours a day, 7 days a week. Aerial spraying to clear head-room for established conifers and to kill off scrub brush before planting averages 9,500 acres annually, while distribution of Douglas-fir seed by copter covers 15,000 acres.

Under the direction of Weyerhaeuser's Longview Branch rehabilitation forester, Bob Johnson, the year's helicopter spraying begins on March 1. Flying from treetop level up to several hundred feet over the 3,500-foot elevation, Douglas-fir mountain terrain, Evergreen's spray gear-equipped Hiller attacks unwanted stands of still dormant deciduous trees and brush with a lethal bath of 245T and diesel fuel. Ten gallons per acre is the prescription to permeate the bark.

About the first of July each year, the two 305-hp Hiller 12E's, each loaded with 85 to 100 gallons of spray on every run, take to the air again with a foliar spray to treat other sites which are not receptive to dormant spray. Actual seeding of the crop to be harvested some 80 years later takes place in November, December, and January. During this final and most critical phase, Evergreen's owners, Delford Smith and Quay Jorgenson, work in close cooperation with Weyerhaeuser foresters to tailor seeding on an almost acre-by-acre basis.

One large contributing factor to the cost of reforestation by any method is the $14 per pound price of good quality conifer seed. Besides their cost, the seeds are highly sensitive to contact. This posed a problem: how to propel them over a wide area without damaging them. Letting them fall from a hopper wouldn't take full advantage of the copter. Part of Evergreen's success in keeping seeding costs down is the development of its own seed broadcaster which gently yet evenly distributes the seed over an 80-foot swath while maintaining a steady 45-mile per hour calibrated speed.

Lake States Starts Research Program on Forest Engineering

A new cooperative research program in Forest Engineering will be established by the U. S. Forest Service on the Houghton campus of the Michigan College of Mining and Technology, according to J. R. Van Pelt, president of Michigan Tech.

The purpose of this new facility, to be known as the Northern Forest Engineering Laboratory, will be to solve engineering problems associated with forest management and utilization peculiar to the hardwood forests of northern and eastern United States.

The staff of this Federal laboratory will cooperate closely with Tech's experts in the Ford Forestry Center at Alberta, Michigan, and the Forest Products Research Division at Houghton. The laboratory will adjoin the site of the future building for the Forest Products Research Division, so that the two groups can work together conveniently.

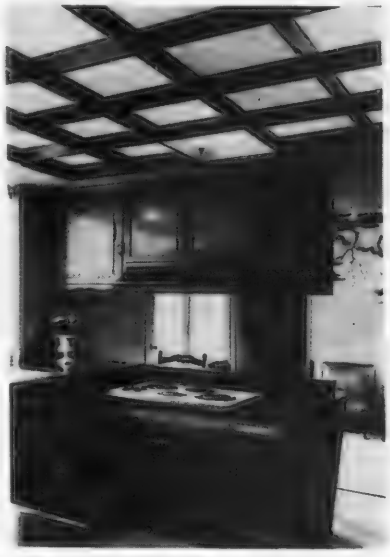
"Forest management in recent years has become intensive," says Dr. Hereford Garland, director of Tech's Forest Products research program. "But the engineering of machines, instruments, tools and methods to be used in forest operations has not kept pace with our knowledge of the techniques of good forest management. Much research along this line is needed. This is why we are so glad to see the U. S. Forest Service undertake this new project."

It is expected that work will be done on the design of equipment for harvesting and handling of logs and other forest products, tree planting, and forest fire fighting. Studies will be made of watershed engineering, forest road construction, soil stabilization, and scientific instruments adapted for use in forest management.

The Forest Service chose the Michigan Tech campus as the site for its new Forest Engineering facility because Tech is one of the country's larger engineering colleges and is located in the heart of one of the nation's major forest regions. In addition, the new program fits uniquely well with Tech's established programs in forestry. These include the Department of Forestry, which gives instruction leading to the degree of Bachelor of Science in forestry, the Forest Products Research Division, which serves the forest industries of the state through research, and the Ford Forestry Center, which has the mission of research and demonstration in forest management.

The new U. S. Forest Service facility at Houghton will concentrate on engineering problems in the northern and eastern forests. Other laboratories will serve the South and West, where problems are different because of differing climate, terrain and forest types.

Mr. M. B. Dickerman, Director of the Lake States Forest Experiment Station of the U. S. Forest Service, has announced the appointment of Rulon B. Gardner as the first staff member of the Northern Forest Engineering Laboratory. He comes to Houghton from the Juneau, Alaska office of the U. S. Forest Service where he has been Branch Chief in charge of structures, hydraulics and equipment management. One additional appointment is expected in the near future. These appointments are regarded as the nucleus of a staff of engineers and technical experts who will be stationed on the Houghton campus of Michigan Tech. No date has been set for the construction of the new laboratory.



Luminous Ceilings Provide New Market Potential

Luminous ceilings of translucent fiberlass and decorative wood framing, such as the one in the kitchen pictured above, have achieved top popularity in new building or remodeling projects. Numerous building supplies dealers are capitalizing on the new idea, and boosting their sales and profits, reports D. S. Perry, president of Filon Plastics Corp.

NEW PRODUCTS *and Literature*

New Three-Wheel Vehicle

A new, low-cost three-wheel vehicle, designed for a wide range of "off-the-road" towing and light hauling applications, has been introduced by Cushman Motors, Lincoln Neb., a subsidiary of Outboard Marine Corp.

Named the Cushman Haulster, the new unit is especially suitable for moving men and materials in industrial plants, lumber mills, parks, golf courses, or other areas where the vehicle is not required to travel on city streets or highways. It is equipped with a special transmission which provides a safe top speed of 14 miles per hour for in-plant operation. In low gear it develops 470 pounds drawbar pull, giving it the power to transport full payloads up steep grades and ramps.

The unit is available in two body styles: a pickup type rear box, or a chassis model, each having a payload capacity of 800 pounds. Compact and highly maneuverable, the Haulster can operate in a 4½-foot passageway, and has a turning radius of 90-inches. Additional information is available.

Circle Item 1

New Literature on Chipper Knives

A 4-page guide and specification insert on new, long-life chipper knives for the pulp and paper industry is now available from United Shoe Machinery Corporation, whose entry into the machine knife field was just recently announced.

The brochure covers the outstanding features of these knives, whose quality is said to be closely controlled by exacting manufacturing and heat-treating requirements, and whose life has been found to equal or exceed that of conventional knives under various conditions of operation. The specification sheet enables the prospective user to detail the knife design, machine and operating data for specific mill conditions. It contains a slot, lock and groove guide for design reference. Copies are available.

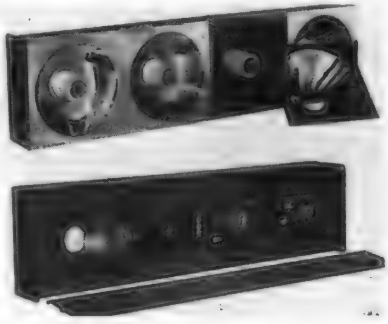
Circle Item 2

Economical Brush Disposal

Improved safety and economy in disposing of tree trimmings result from two new accessories on Fitchburg Chippers. Mr. W. N. Forman, President of the Fitchburg Engineering Corporation, reports that a new safety stop switch will become standard on all new models. Located at the top of the feed apron, one flip of this switch stops the Chipper within seconds for added safety.

A second switch, also located at the rear for easy use, will give immediate control of the motor without having to move from the feeding position. This solenoid switch will idle the motor between actual feeding operations, thus decreasing gasoline consumption, reducing engine wear, and making quieter operation possible. More information may be obtained.

Circle Item 3



Infrared Generators Installed From Back

The Dry Clime Lamp Corp., Greensburg, Ind., has just announced two major improvements in its line of driQuik ceramic type electric infrared oven sections for industrial use. All driQuik ceramic infrared generators will now be installed from the back of the sections. This is a "first" in the industrial infrared field. Until now, all infrared units have been installed from the front of the sections and often required two persons to complete an installation. With the new method of installing driQuik replacement units from the back, all installations can be made by one person, and can even be made while the oven is in operation.

The second major improvement is in the design of the reflectors. The new, improved driQuik reflectors may be removed for cleaning purposes without removal of the infrared generators, which was necessary on former models. This is also a "first" in the industrial infrared field. More information may be obtained.

Circle Item 4

New Panel Saw Literature

An illustrated 6-page brochure on their complete line of panel saws is now available from the C. O. Porter Machinery Company. Together with complete specifications on available sizes, feed speeds, capacities and other operational data, this new literature features a unique, "engineer-it-yourself" specifying guide for saw infeed and outfeed tables. According to the manufacturer, this information enables any customer to easily and accurately estimate his own saw and table dimensions and types. Write for your copy.

Wood Preservative

Chemical Products Division, Darworth Incorporated introduces a new wood preservative, Cuprinol No. 224, for the woodworking industry. The active fungicide in Cuprinol No. 224 is an organo-tin compound manufactured by Metal & Thermit Corporation.

Cuprinol No. 224 is a nonswelling, paintable, water repellent wood preservative conforming to or exceeding National Woodwork Manufacturers' Association Specifications, and Federal Specification TT–W–572. Wood treated with Cuprinol No. 224 is afforded excellent protection against decay, termites, and other wood destroying insects. It is supplied in low cost, concentrated form easily diluted at site of use.

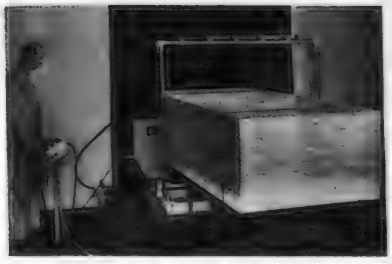
Circle Item 5

New Catalog on Band Saw Blades

A colorful new 6-page catalog has been published by Frank W. Swett & Son, manufacturer of Nickle Steel wood-cutting band saw blades. An interesting feature of the new catalog is a sequence of illustrations which show the seven separate steps required to convert steel coil into finished Nickle Steel band saw blades. In addition, separate catalog sections explain the advantage of Swedish steel as blade metal, and skip-tooth design for wood-cutting bands.

Instructions for proper saw tooth selection plus a simplified ordering system are also special features of this new catalog. The new catalog, complete with the latest Nickle Steel price list, is available to woodworkers on request.

Circle Item 6



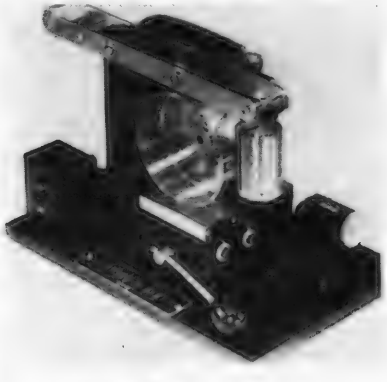
Machine Automatically Unitizes Plywood Panels

High volume unitizing of plywood panels is now possible with any degree of automatic control with a new steel strapping machine manufactured by Acme Steel Company, Chicago.

The machine is the Acme Steel F7A(4), latest model in the firm's recently announced F7 series of strapping machines. The machine incorporates a new basic strapping mechanism, described by the firm as the lightest, lowest cost unit yet developed.

In addition to the basic strapping mechanism, F7A(4) primarily consists of a base, a pneumatically actuated carrier which supports the strapping mechanism and moves it in and out of strapping position, a full strap track, control console, plus limit switches or sensing devices for fully automatic operation. Additional information may be obtained.

Circle Item 7



Wet-Rub Tester

Thwing-Albert Instrument Company offers a new Wet-Rub Tester which provides a reliable method for the quantitative evaluations of coated papers. The Wet-Rub Tester was developed at the Research Laboratories of Corn Products Refining Company, Argo, Illinois.

The test method involves wrapping the test specimen around a stainless steel drum and rotating it against an idler roll covered with smooth-surfaced gum rubber. This provides a slip-free operation.

The effective weight of the idler against the sample may be varied by means of auxiliary weights supplied with the instrument. The weight of solids removed from the sample during a predetermined number of revolutions is readily obtained by evaporation of the reagent grade water through which the sample rotates during test.

The instrument and the associated test procedure exhibit exceptional repeatability. For more information, write.

Circle Item 8

Lumber Industry Facts

A new section of *Lumber Industry Facts,* statistical handbook tracing more than 350 years of growth and progress in the American lumber industry, has been published by the National Lumber Manufacturers Association.

The 56-page booklet contains thousands of facts and figures on forest resources, lumber production, consumption, stocks and shipments, industry employment, exports-imports, and financial statistics. For the first time, data are also included on the wholesale and retail lumber trade, on research expenditures in the industry, and several tabulations are devoted to manufacturing census statistics for lumber and wood products. Free copies are available.

Circle Item 9

Direct Drive Chain Saw

A professional direct drive chain saw with the cutting power of a geared saw is the newest chain saw in the line of Strunk Power for Modern Living, Inc., Coatesville, Pa., manufacturers of gasoline and electric chain saws, portable pumps, emergency generators, impact tools and electric hammers.

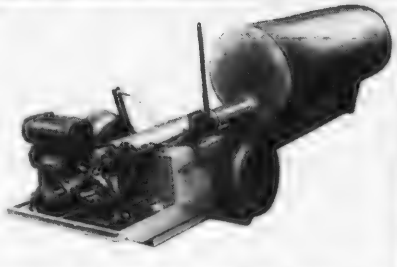
This high horsepower direct drive saw will be good news to the many professional chain saw users who up until this time have had to depend upon geared saws for high power requirement cutting. It will also be good news for the many professional users of direct drive chain saws who have wanted more ruggedness and less complicated assembly, as well as higher power in their direct drive saw without additional weight.

This gasoline chain saw, which was 2 years in development and testing, is felt by Strunk to be the first real challenge to the product supremacy claimed by the larger manufacturers of chain saws. It has performance equal to or superior to any other direct drive chain saw on the market today—displacement is 5.913 cubic inches, engine speed is 7,500 rpm (in operation), and the average cutting speed of the chain is 3,712 feet per minute. More information may be obtained.

Circle Item 10

LICKITY LOG SPLITTER

ANOTHER PIONEERED PRODUCT OF THE WACO AIRCRAFT COMPANY - - TROY, OHIO, U.S.A.



Smooth 18 ton hydraulic power splits big profits for you from the toughest woods, including American Elm. 7 HP trailer unit squats under own power to receive large logs without "dead" lift. Has 2 speeds, auto-shift and auto-stroke. 26" ram travel splits up to 34" lengths, any dia.—or, with extended frame and adjustable wedge, splits up to 52" lengths, any dia. Write for details.

DEALER INQUIRIES INVITED

New Model "L" which will split logs of any diameter up to 8½ feet in length is now available.

THE WACO AIRCRAFT CO., Dept. S, Troy, Ohio

Plywood Panel for Farm Use

Ag-Ply, a new plywood panel engineered specifically for farm uses, is now available nationally, according to Douglas Fir Plywood Association whose engineers developed the new product. A general purpose outdoor building material, Ag-Ply is a low-cost panel intended to serve a rapidly growing farm market that last year consumed more than a billion square feet of softwood plywood. Already the second biggest market for western plywood, the farm market is expected to require 3 billion square feet annually by 1965 according to projected figures.

The new panel developed to serve this market is bonded with the same waterproof adhesives used in manufacturing marine fir plywood. Ag-Ply must meet the same rigid quality control tests established in the Commercial Standard for exterior type fir plywood. However, Ag-Ply is primarily a performance material, and does not have the fine appearance of the higher grade marine panels. Ag-Ply is unsanded and can have a limited number of open defects. This does not impair performance, but keeps costs low. Write for more details.

Circle Item 11

Saw Distributor

Eastern Machinery, Inc., Syracuse, N. Y., has been appointed a distributor for the Wright Saw division of Thomas Industries Inc., Louisville, Ky. Eastern Machinery will handle sales of the company's gas-driven power blade Wright Saw in Vermont and a number of counties in New York state. The Wright Saw line of gas-operated power saws includes a 20-inch blade model (5020-A) and a new, compact 16-inch blade model (2016) which weighs only 19 pounds, including blade and guide. The Wright Saw is the only power saw on the market with a reciprocating blade, which moves back and forth like a hand saw at the rate of 10,000 strokes per minute. The saws are exceptionally safe since they require no chain for operation, are versatile in that they can cut in all positions, and are easy to handle because of their light weight.

Twenty-Ton Capacity Fork Lift

A new diesel-electric fork lift that can handle up to 40,000-pound loads and operates on either paved or unpaved surfaces has been introduced by R. G. LeTourneau, Inc., Longview, Texas. Electric wheel drive and big wide-base tubeless tires provide flotation and traction for rough terrain use.

The Series FLT-20 Fork Lift Truck is expected to have many applications in industry where heavy material is presently being handled by cranes. The first units shipped are being used by a pipe manufacturer to handle palletized pipe in their storage yard as well as load trucks and rail cars.

The machine is completely electrically powered—eliminating clutches, transmissions, drive shafts and hydraulic lines. Individual electric gearmotors placed at the point of work power the hoist, rack tilt, and rear wheel steering. It is similar in design to the LeTourneau Log Stacker which

has been in use since 1955 in the lumber industry to unload trucks and handle logs in the millyard.

The three-wheel unit is powered by a 210-horsepower diesel engine driving AC and DC generators. All controls are governed by simple electric switches. The control console is part of a revolving seat assembly that permits the operator to swivel and face the direction of travel. The two front wheels are powered by DC electric motors mounted inside the rim. Overall length, including forks, is 34 feet, 9 inches and the turning radius is 25 feet. More information may be obtained.

Circle Item 12

Research and Management

"Can the Research Scientist Acquire a Management Attitude?" is the title of, and the basic question underlying, a printed discussion now being offered by Battelle Memorial Institute to representatives of industry concerned with research and development. Written by M. R. Nestor, Battelle's manager of project development, the statement is one of a series on the procedures and characteristics of contract research for industry being published by the Columbus, Ohio, research center.

In this statement, Nestor makes the point that industrial management people and research professionals have much in common, including a high degree of creativeness. Industry's practical needs and the professional's desire for creative freedom are compatible, he asserts. Copies of this discussion are available.

Circle Item 13

New Flakeboard

"Collins Flakeboard" will be the trade name of a new flakeboard to be produced at the newly completed $2,000,000 Chester, California plant of Collins Pine Company, one of the nation's oldest lumber firms.

Elmer R. Goudy, general manager of the company, said that exclusive use of selected Sierra softwoods will give the new Collins flakeboard an exceptional machineability and ultra-smooth faces and edges. The recently developed machinery used by the Collins company will produce a board with outstanding uniformity. Around-the-clock quality checks will ensure an unvarying standard of high quality. The flakeboard will be made in thicknesses of from ¼ to 1¼ inches and in sheet sizes up to 5 feet by 10 feet.

All-Purpose Wood Preserver

A new all-purpose water repellent liquid preservative to protect wood against insects, termites, decay, surface mold, mildew and fungi has been announced by Osmose Wood Preserving Company of America, Inc. Trade named, Oz Wood Preserver, the product contains "Butinox," a liquid organo-tin compound (tributyltin-oxide) produced by Metal and Thermit Corporation. Oz Wood Preserver offers the industrial trade a superior single compound which can be used for any application. Laboratory tests have proved it twice as toxic to decay, bacteria and fungi but less toxic and irritating to humans, the company states. Being noncrystalline, Oz does not stain or leave a residue to complicate subsequent painting.

The water repellent in Oz reduces warping, shrinking, swelling, checking and grain raising. It improves paint holding properties and dimensional stability through weather changes and eliminates paint blistering and peeling.

Oz Wood Preserver conforms to the definition of a "non-swelling, paintable, water repellent wood preservative" as defined by the U.S.D.A. Forest Products Laboratory. It meets or exceeds the requirements of National Woodwork Manufacturers Association and Federal Specification TT-W-572.

Baseball Bats

The white ash of New York State, the primary source of stock for baseball bats, may be in danger of extinction, according to E. W. Littlefield, N. Y. State Dept. of Conservation. A virulent new disease of unknown origin, ash-dieback, has been found in recent years to be killing white ash trees in many parts of the state. Trees of all ages are affected. A partial survey of eastern New York has revealed that in 18 counties, 64 percent of the white ash trees are dead or dying. In commercial woodlots, up to 70 percent of the trees are in various stages of decline as a result of the disease. The disease may have serious impact on the wood-using industries that depend on white ash, which is used extensively in the manufacture of furniture, tool handles, toys, woodenware and novelties as well as baseball bats.—*Conservation News,* July 1, 1961.

Expansion Program Planned by Southern Pine Lumber Co.

A two-phase expansion program totaling $1¼ million for the Fiber Products Division has been announced by Southern Pine Lumber Company of Diboll, Texas.

Completion of the expansion program will take from 18 to 24 months, according to Carrol Allen, Vice President.

The program calls for immediate expansion of facilities that will include more pulping capacity, added machine production capacity and an additional warehouse. The major portion of the $1¼ million project will go to the added machine production for a new line of decorated products and other specialty items, Allen said.

Carl H. Shepherd, Jr., former plant superintendent, has been named production manager of the Fiber Products Division.

Koppers Establishes Panel Department

B. R. Sarchet will head a Panel Department established by Koppers Company, Inc., it was announced by Walter P. Arnold, Executive Vice President. Previously the Company's building panel activities had been carried on by a development group which operated within the Plastics Division. The decision to establish a separate department was brought about by the increasing scope of Dylite Panel activities which now touch several of Koppers Divisions, both nationally and internationally, Mr. Arnold said.

In addition to their use in homebuilding, panels made by Koppers, which have been in the research and development stage for many years, are now finding a commercial acceptance in schools, churches, commercial refrigerators, motels, apartments, industrial buildings and office buildings.

New Distributor For Fan-Air Systems

Wilco Machine Works, Inc., of Memphis, Tenn., was recently appointed Southeastern distributor for Fan-Air Systems, Inc., developers of a new and uniquely proficient method of kiln drying.

In making the announcement, Hubert Gray, general manager of Fan-Air Systems, Inc., said: "We are particularly pleased with the appointment of Wilco Machine Works, Inc., as our distributor. The firm has long been noted for its experience in sales and engineering of forestry and woodworking equipment and is well qualified to offer complete sales and service of Fan-Air kiln systems to the industry."

If it's a question about wood preservatives...

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NOXTANE
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WOODTREAT A
A 10% Penta emulsion paste. Gives maximum protection to standing poles, piling, cutoffs, structural timbers. Applied by hand scoop, brush, paddle or mechanical spray. Clean to handle . . . not highly toxic.

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WOOD TREATING

New Cutawl Company Formed

The newly formed Cutawl Corporation, Bethel, Conn., a subsidiary of Foredom Electric Co., Inc., manufacturers of miniature power tools, has purchased the Cutawl Division of International Register Co. The Cutawl is a portable high-speed cutting machine that will cut every sort of design and shape in a wide variety of sheet materials including wood, plastic, metal, linoleum, composition, etc.

Long considered indispensable in the display and sign fields, the new Cutawl is particularly suited to the making of templates and production samples, patterns, gaskets, linoleum inlays, and a multitude of other products. It has a unique swivel head which permits a 360° traverse of any pattern or design without changing direction of the Cutawl. Cutting can be started anywhere as the Cutawl makes its own starting hole and it leaves a smooth edge with no further finishing required. It will cut perfect circles as small as ¾-inch diameter or as large as 48 inches with extreme accuracy and speed. The Cutawl is safe to use and requires no special skill or training. It has adjustable stroke and speed.

Fire Safety

The Atomic Energy Commission has noted the fire safety figures of sheet polyethylene as used in construction in a letter to the Manufacturing Chemists' Association. Tests show, said AEC Safety Program Specialist J. P. H. Kelly, Sr., that sheet polyethylene presents a less serious fire hazard than canvas tarpaulin. According to MCA, the AEC test reveals that "the melting point is so low that hot objects coming in contact with the polyethylene melt through, rather than ignite it." Kelly also stated that the AEC and its contractors have been using polyethylene sheeting for many persons including enclosures for construction work, covering construction materials and as an aid for curing concrete pours.

COMING EVENTS

Oct. 11–13: FPRS Mid-South Section Meeting, King Edward Hotel, Jackson, Miss.

★

Oct. 15–21: National Forest Products Week.

★

Oct. 16–17: FPRS Pacific Northwest Section Meeting, Qualicum Beach, Vancouver Island, B. C.

★

Oct. 19–20: Annual Fall Meeting, FPRS Midwest Section. Theme: Wood Composition Board, McCormick Place, Chicago, Ill.

★

Oct. 20: Annual Fall Meeting, FPRS Northern California Section, Fort Bragg, Calif.

★

Oct. 23–25: Annual Meeting Canadian Wood Development Council, Timberline Hotel, Banff, Alberta, Canada.

★

Oct. 27–28: FPRS Inland Empire Fall Meeting, Washington State University, Pullman, Wash.

★

Nov. 1–3: American Forest Products Industries, Inc., Annual Meeting, Mayflower Hotel, Washington, D. C.

★

Nov. 1–3: National Retail Lumber Dealers Assoc., Annual Meeting, Conrad Hilton Hotel, Chicago, Ill.

★

Nov. 2–3: Annual Meeting FPRS Carolinas-Chesapeake Section, Battery Park Hotel, Asheville, N. C.

★

Nov. 2–3: FPRS Northeast Section Fall Meeting, Hotel Prince George, New York City.

★

Nov. 4–7: National Retail Lumber Dealers Association, Exposition, McCormick Place, Chicago, Ill.

★

Nov. 6–8: 1961 Pacific Logging Congress, St. Francis Hotel, San Francisco, Calif.

★

Nov. 6–9: National Lumber Manufacturers Assoc. Board of Directors and Committees, Annual Meeting, Shoreham Hotel, Washington, D. C.

★

Dec. 7: National Institute of Wood Kitchen Cabinets, Annual Winter Meeting, Sheraton Towers, Chicago, Ill.

★

Dec. 12–13: National Oak Flooring Manufacturers Assoc., Annual Meeting, Peabody Hotel, Memphis, Tenn.

★

Jan. 17–19, 1962: Appalachian Hardwood Manufacturers, Inc., Annual Meeting, Netherland Hilton Hotel, Cincinnati, O.

Oregon Reforestation

The reforestation of 21,586 acres of forest land in Oregon with over 5.6 million tree seedlings and 10,330 pounds of tree seed during the 1960 to 1961 planting season was accomplished by the state forestry department at a cost of about $291,000, it was announced recently by State Forester Dwight L. Phipps. Some 13,822 acres of this was seed by helicopter at a cost of about $8.20 an acre, while 7,764 acres were planted to trees for a total cost of $22.88 per acre or about $30 per one thousand trees, he added.

The Tillamook Burn, widely acclaimed as the greatest conservation effort ever undertaken, received almost 4.4 million of these trees and 9,420 pounds of the seed to add some 18,444 acres of green to the 255,000 acres of state lands in this project of reforestation that is over two-thirds completed.

Mile-Long Plywood Panels Available

If you need a panel of fir plywood a mile or two long and 10 feet wide you can buy it—if you can figure a way to get it from the mill to your job site. Six major manufacturers have announced availability of panels 8 feet or more wide and "any reasonable length" in most instances, although two of the six prefer to limit length to 24 to 50 feet. Panels wider than 5 feet are scarfed along the grain

In most cases panels can be supplied in any grade, although sizes of sanding equipment limit some of the six. Manufacturers with equipment for producing giant panels include Cascades Plywood Corp.; Diamond Lumber Co.; Georgia-Pacific Corp.; International Paper Co.; Simpson Timber Co., and U. S. Plywood Corp.

Bark Mulch Production

A bark mulch, first product to come from its newly created Product Development Department, will be produced in quantity shortly, it was announced today by J. B. Edens, President, Southwest Forest Industries, in his Annual Report to stockholders. Equipment for processing tree bark into a mulch for use in lawn care and general agricultural purposes is now being installed at the company's paper and pulp mill in Snowflake Mills, Arizona.

Other new items being considered under the company's research program are laminated and end-edge glued products, as well as refinement of cut parts for industrial users, the stockholders were told by Edens.

FPRS FOREST PRODUCTS JOURNAL VOL. XI, NO. 10 OCTOBER, 1961

V. P. MINIUTTI
E. A. MRAZ
J. M. BLACK
Forest Products Laboratory,[2] Forest Service U. S. Department of Agriculture

measuring the effectiveness of water-repellent preservatives[1]

Results of 4 years of outdoor exposure tests were compared with results obtained with various laboratory test methods.

FOR MORE THAN 20 YEARS, millwork manufacturers have dipped exterior millwork items for 3 minutes in water-repellent preservatives. Experience indicates that the treatment protects the wood against attack from decay and stain fungi, reduces swelling and shrinking of the wood, and prevents the accumulation of water in the joints of millwork items, thereby improving the performance of paints on treated millwork.

Many laboratory test methods have been developed to measure the water repellency of water-repellent preservatives. The National Woodwork Manufacturers Association is currently endorsing the swellograph method[3] and requires that treating solutions develop a minimum water repellency of 60 percent in this test. The question has been raised, however, as to whether or not other laboratory test methods might better reflect the protection given by water-repellent preservatives to exterior millwork in service. The research covered in this report, started early in 1956 at the Forest Products Laboratory in cooperation with the National Woodwork Manufacturers Association, was designed to answer this question.

This report outlines the procedures used, gives the results of the weathering tests during 4 years of weathering, and compares results from the laboratory and weathering tests.

Test Solutions

The 11 solutions tested consisted of 1 preservative, 1 water repellent, and 9 water-repellent preservatives that had a wide range of water repellency in the swellograph test. The solution numbers, water repellencies in the

[1] A contributed paper approved for publication July, 1961; this study was done in cooperation with the National Woodwork Manufacturers Association.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Water repellency test method NWMA–M–2–51 of the National Woodwork Manufacturers Association.

Which one of several laboratory methods of measuring the water repellency of water-repellent preservatives best reflects the effectiveness of the solutions in weathering tests? The U. S. Forest Products Laboratory tested a preservative, a water repellent, and nine water-repellent preservatives by seven laboratory methods and by two weathering methods that have been in progress for 4 years. Here are the results.

swellograph test, and descriptions of the solutions are given in Table 1.

Definition of Water Repellency

Treated and untreated wood specimens were exposed under various test conditions to liquid water and water vapor. The term "water repellency" refers to the ability of the treatments to repel or retard the movement of water in one or both of its forms.

The equation used to calculate water repellency in percent is:

$$\frac{\text{change in untreated controls—change in treated specimens}}{\text{change in untreated controls}} \times 100$$

The changes used in the calculations were changes in dimension, weight, or cup of the specimens. With this equation, 100 percent water repellency means that no change occurred in the treated specimens, 0 percent water repellency means that the treated specimens changed as much as the untreated controls, and a negative water repellency means that the treated specimens changed more than the untreated controls.

Preparation of Specimens

Specimens were prepared for nine test methods, including 1) swellograph, 2) flowing water, 3) swellometer, 4) water spray, 5) cupping, 6) weight gain at 30 to 80 percent relative humidity, 7) weight gain at 65 to 97 percent relative humidity, 8) right-angle specimen, and 9) window sash. The first seven are laboratory tests and 8) and 9) are weathering tests.

Selection: All specimens were made of kiln-dried ponderosa pine sapwood from one source. The carefully selected wood was straight grained, clear, and of average density for the species.

For the weight-gain test, 65 to 97 percent relative humidity, one untreated control specimen was crosscut from a board, followed by three specimens which were to be treated. For the other laboratory tests, an untreated control specimen was cut adjacent to each specimen to be treated. Five pairs of specimens were used for each solution.

The right-angle specimens were placed at random into sets of 10. One set was used for treatment with each solution, and one set was to be left untreated. Five of each set of 10 specimens were painted.

Sixty-five window sash were supplied by the millwork manufacturer who furnished the ponderosa pine stock. Random selection was used to pick 5 sash for treatment with each solution and 10 to be left untreated. Five untreated sash and all of the treated sash were painted. Treated but unpainted sash were not tested.

Treating: The laboratory-test specimens were dipped for 30 seconds in the treating solution, but the window sash and right-angle specimens were dipped for 3 minutes. Specimens were treated with all solutions for all methods except the swellometer. This method was added late in the laboratory-test program and was used to evaluate only 4 of the solutions, numbers 4, 5, 10, and 11.

Each window frame in which a treated sash was placed for outdoor exposure received a brush coat of the same solution used to treat the sash that was installed in it. The solution was brushed on all surfaces that could be reached before the sash was installed.

Glazing: The window sash were glazed after they were treated.

Painting and Varnishing: The specimens for the tests of cupping and weight gain at 65 to 97 percent relative humidity were painted on edges and ends with one coat of thick white-lead paint followed by two coats of aluminum enamel before treatment. After treatment, one broad face of the cupping specimens was painted with three coats of aluminum enamel.

The window sash were painted and varnished after they were glazed, while the right-angle specimens were painted after being treated. All surfaces of the right-angle specimens were painted, but with the window sash, paint was applied to only that portion of the "outdoor" surface of the sash that could be reached after a sash was installed in a window frame.

Three coats of paint were applied, consisting of a coat of titanium-lead primer and two coats of titanium-lead-zinc house paint. The three coats were applied at spreading rates calculated to give a total dry film thickness of about 0.005 inch. From 2 to 7 days of drying time elapsed between coats of paint. After the "outdoor" surface was painted, two coats of interior varnish were brushed on the surfaces of the "indoor" side of the sash that could be reached after a sash was installed in a window frame. Three days of drying were allowed between coats.

The window frames received two coats of the same paints used in the "outdoor" surfaces of the sash. The prime coat was brushed on all surfaces that could be reached before a sash was installed, and the top coat was brushed on all surfaces that could be reached after a sash was installed. The painting was done by an experienced painter, but the amount of paint applied was not controlled or recorded.

Conditioning: The specimens used to check cupping and weight gained at 30 to 80 percent relative humidity were conditioned to constant weight at 30 percent relative humidity and 80° F. All others were conditioned at 65 percent relative humidity and 80° F. This conditioning was done both before and after treatment and before test.

Test Methods

Some of the tests involved exposure of specimens to water, others to water vapor, and still others to both water and water vapor by weathering at Madison, Wis. The type of test and brief description of each follows.

Exposure to Water: *Swellograph:* Specimens, 1/4 by 1 1/2 by 10 inches in the longitudinal, radial, and tangential directions respectively, were immersed in water in the swellograph apparatus. The tangential swelling of treated and untreated specimens was recorded by graph over a period of 30 minutes.

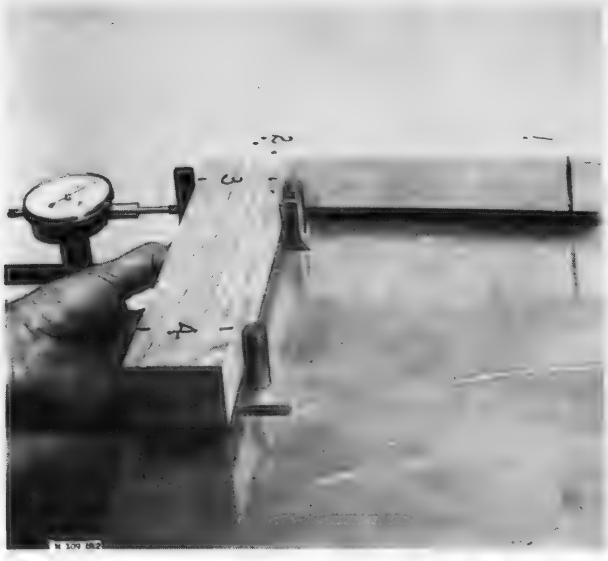

Fig. 1.—Right-angle specimen with numbers at the points where dimensions were measured. Thickness was measured at 1 and 2 and width at 3 and 4.

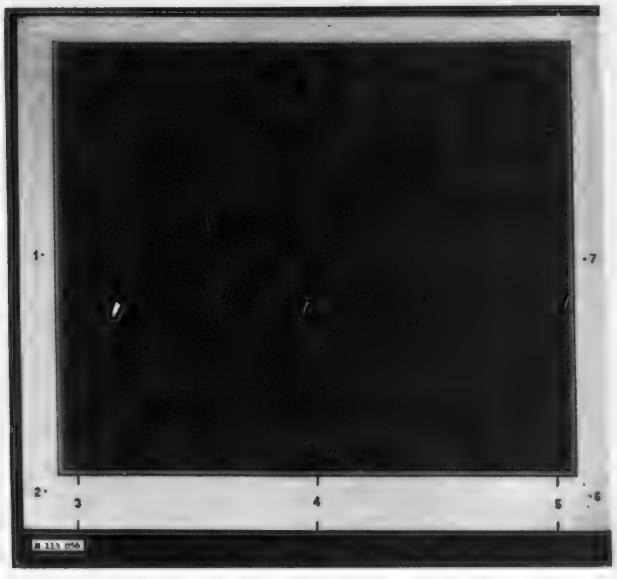

Fig. 2.—Window sash specimen with numbers at the points where dimensions were measured. Thickness was measured at 1, 2, 6, and 7 on the stiles and width at 3, 4, and 5 on the bottom rail.

Swellometer: Swellograph specimens were immersed in water in the swellometer apparatus. The tangential swelling of treated and untreated specimens was measured at the end of 30 minutes.

Flowing Water: Swellograph specimens were held in the swellometer rack at an angle of 60° from the horizontal. Two streams of water were flowed over one face for 24 hours. The tangential swelling of treated and untreated specimens was measured after elapsed intervals of 15, 30, and 45 minutes, and 1, 2, 4, 8, and 24 hours.

Water Spray: Swellograph specimens were held in the swellometer rack at an angle of 10° from the horizontal. One face of the specimen was given eight 5-second sprays at 15-minute intervals. The tangential swelling of treated and untreated specimens was measured 15 minutes after each spray.

Exposure to Water Vapor: *Cupping:* Specimens, ¼ by 3 by 12 inches in the radial, longitudinal, and tangential directions respectively, were conditioned to constant weight in air at 30 percent relative humidity and a temperature of 80° F. They were then moved into a chamber that was maintained at 80 percent relative humidity and a temperature of 80° F., where cupping of the specimens in the tangential direction was measured at 1-hour intervals for 14 hours.

Weight Gain at 30 to 80 Percent Relative Humidity: The specimens for tests of weight gained at 30 to 80 percent relative humidity were the same specimens used in the cupping tests. After they were moved from the 30 to 80 percent relative humidity room, they were weighed daily for 7 days.

Weight Gain at 65 to 97 Percent Relative Humidity: Specimens, ⅝ by 4 by 8 inches in the radial, tangential, and longitudinal directions respectively, were conditioned to constant weight in air at 65 percent relative humidity and a temperature of 80° F. They were then moved into a room that was maintained at 97 percent relative humidity and a temperature of 80° F. and weighed daily for 7 days.

Weathering at Madison, Wisconsin: *Right-Angle Specimen:* Specimens simulating a bottom corner of a window sash were made of two 1¾- by 2- by 8-inch pieces joined by a mortise-and-tenon joint. They were exposed to the weather under a narrow ledge which gave some protection from the weather. The specimens were weighed and dimensional changes measured at four points (Figure 1) eight times each year for 3 years and four times during the last quarter of the fourth year. Weights and dimensions were taken after prolonged periods of wet and dry weather to obtain as closely as possible the maximum and minimum values for each year.

Window Sash: Glazed window sash of a standard size, installed in window frames that were shielded on the "indoor" side with plywood, was exposed to the weather with the "outdoor" side facing south. The specimens were weighed and dimensional changes measured at seven points (Figure 2) eight times each year for 3 years and four times during the last

NWMA Foreward

A report of the history and development of wood preservation for millwork was published in the October, 1958, Forest Products Journal (vol. VIII, no. 10) pages 61-a–65-a. Reference was made in that report to a cooperative research project of the U. S. Forest Products Laboratory and the National Woodwork Manufacturers Association which was begun early in 1956, to determine which of the several laboratory methods of measuring the water repellency of water repellent preservatives best reflects the effectiveness of the solutions in weathering tests. On completion of numerous laboratory tests and 4 years of outdoor exposure tests, the following conclusions were drawn:

1. Correlation with the weathering method was about equally good for four laboratory methods, including the swellograph (present NWMA standard).
2. The 3-minute dip of window sash in a good water-repellent preservative before painting will materially reduce or eliminate stain and decay fungi, end checking, cracking of the glazing compound, excessive swelling, and paint failure.
3. Treatment with a good water-repellent or water-repellent preservative affords better protection than treatment with a preservative only.

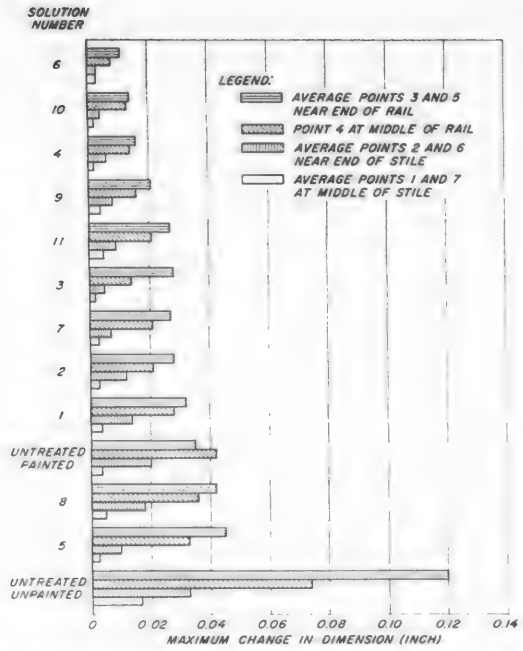

Fig. 3.—Maximum changes in dimensions of window sash during the fourth year of weathering. All treated sash were painted. The changes (averages of 5 specimens) were in the width of the bottom rail at points 3, 4, and 5 (original dimensions about 3.14 inches at 12 percent moisture content) and in the thickness of the stiles at points 1, 2, 6, and 7 (original dimensions about 1.35 inches at 12 percent moisture content).

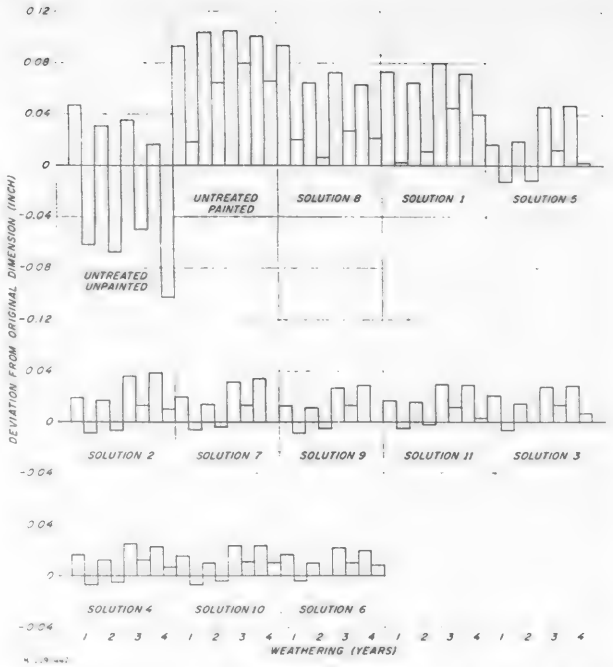

Fig. 4.—Annual maximum and minimum dimensions shown as deviations from the original dimensions at points 3 and 5 on treated and untreated window sash during 4 years of weathering. All treated sash were painted. Each deviation is the average of 5 sash. The original dimensions at points 3 and 5 were about 3.14 inches at 12 percent moisture content.

quarter of the fourth year. Weights and dimensions were taken after prolonged periods of wet and dry weather to obtain as closely as possible the maximum and minimum values for each year.

Results

Weather data collected near the test site during the 4 years of exposure of the window-sash and right-angle specimens are summarized in Table 2.

The differences between the maximum and minimum dimensions of the window sash observed during the fourth year of weathering are shown in Table 3 and Figure 3.

The annual maximum and minimum dimensions at points 3 and 5 and weights of the window sash for each year of weathering are given in Table 4. Figure 4 shows annual maximum and minimum deviations in dimensions at points 3 and 5.

Table 1.—DESCRIPTION OF TEST SOLUTIONS

Type of solution	Solution number	Water repellency [1] Percent
Current industrial water-repellent preservatives supplied by three manufacturers.	4	77
	5	53
	11	82
Water-repellent preservatives, intended to have high water repellency, supplied by three manufacturers.	3	61
	6	83
	9	67
Water-repellent preservatives supplied by three manufacturers, intended to have water repellency of less than 60 percent as determined by the swellograph method (water-repellent test method NWMA-M-2-51 of the National Woodwork Manufacturers Association).	1	6
	2	28
	7	61
A preservative formulated at the Forest Products Laboratory.	8	4
A water repellent formulated at the Forest Products Laboratory.	10	77

[1] Water repellency in the swellograph test.

Water repellencies obtained in the weathering tests are presented in tables 5, 6, and 7 for 4 years of weathering and in Figure 5 for the fourth year. Water repellencies from the swellograph test are compared with the repellencies from the window-sash test during the fourth year of weathering in Figure 6. Table 8 gives correlation coefficients for water repellencies in the window-sash test compared with those from laboratory tests.

Ratings of the window sash for paint integrity, putty cracks, wood checks and splits, and stains after 4 years of weathering are listed in Table 9.

Figure 7 shows discoloration resembling that of stain or decay fungi on the "indoor" side of untreated window sash. Similar stains also appeared on the "indoor" side of sash treated with water-repellent preservatives No. 1 and preservative No. 8. They were not as extensive, however, and were not sufficiently intense to show clearly in photographs.

The bottom (down-looking) faces of six of the groups of five right-angle specimens are shown in figures 8, 9, and 10 with the "outdoor" side of a corresponding window sash after 4 years of weathering. They compare

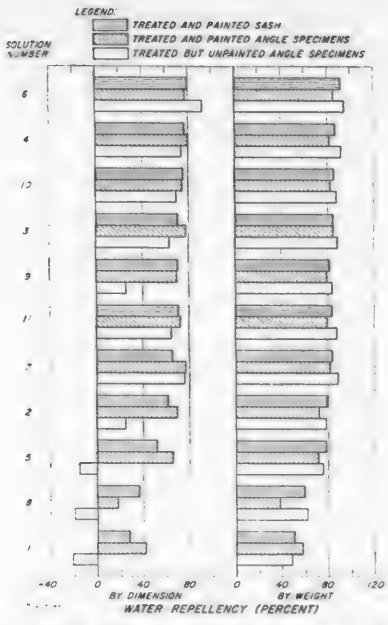

Fig. 5.—Water repellencies for the fourth year of exposure calculated from the maximum deviation from the original measurement in weight or dimension (point 3 on the right-angle specimens and average of points 3 and 5 on the window sash). All controls were untreated but were painted if the treated test specimens were painted.

the effect of paint and no paint (Figure 8), a good preservative and a good water repellent (Figure 9), and a poor and a good water-repellent preservative (Figure 10).

Discussion

Dimensions and Weights of Window Sash: The maximum changes, or difference between maximum and minimum dimensions, of the window sash observed during the fourth year of weathering are listed in Table 3 and plotted in Figure 3. Changes in dimension were averaged for the pairs of points 3 and 5, 2 and 6, and 1 and 7, because the two points in each pair occupied similar positions on the sash (Figure 2) and changed similarly in dimension.

The data in Figure 3 show a striking difference in the effectiveness of the various treating solutions to stabilize the wood in the sash. Near the ends of the bottom rail (points 3 and 5), the maximum change in dimension ranged from only 0.011 inch for solution No. 6 to 0.045 inch for solution No. 5. Figure 3 also shows that, except for untreated but painted sash, the greatest changes in dimension occurred near the ends of the bottom rail. Dimensional changes at the middle of the rail (point 4) were less than those near the ends (points 3 and 5), and changes at the middle of the stiles (points 1 and 7) were less than those near the lower ends (points

Table 2.—WEATHER DATA FOR MADISON, WIS., DURING THE 4 YEARS OF EXPOSURE OF THE WINDOW-SASH AND RIGHT-ANGLE SPECIMENS

Month	Relative humidity		Total precipitation Inches	Relative humidity		Total precipitation Inches
	Average maximum Percent	Average minimum Percent		Average maximum Percent	Average minimum Percent	
	1957			1958		
January	82	52	0.41	88	63	0.52
February	88	58	.38	82	51	.08
March	86	47	1.19	89	51	.38
April	88	43	2.40	86	37	2.73
May	89	55	5.80	80	27	3.93
June	91	47	6.41	90	41	2.16
July	93	50	4.00	92	45	1.69
August	94	49	4.86	91	39	2.06
September	93	46	.95	93	49	2.44
October	91	45	2.14	88	46	2.50
November	89	62	2.91	87	50	2.29
December	88	57	1.41	84	59	.31
Average or total	89	51	32.86	86	47	21.09
	1959			1960		
January	84	57	1.40	86	67	2.19
February	88	60	1.58	87	65	1.14
March	91	59	2.90	95	62	1.93
April	87	40	4.01	87	48	4.02
May	89	45	3.06	87	58	6.26
June	86	41	3.86	89	50	2.09
July	91	43	4.12	98	54	6.04
August	95	57	5.68	98	65	6.18
September	92	47	3.44	94	59	3.90
October	93	62	5.55	88	52	3.32
November	89	61	2.29	93	59	1.47
December	93	68	2.45	78	51	.25
Average or total	90	53	40.34	90	57	38.79

Table 3.—MAXIMUM CHANGES IN DIMENSIONS OF WINDOW SASH DURING THE FOURTH YEAR OF WEATHERING

Solution number [1]	Maximum changes in dimensions [2]			
	Thickness of stiles [3]		Width of rails [4]	
	Average of points 1 and 7 Inch	Average of points 2 and 6 Inch	Point 4 Inch	Average of points 3 and 5 Inch
1	0.0037	0.0143	0.0278	0.0321
2	.0029	.0121	.0206	.0280
3	.0025	.0049	.0140	.0285
4	.0023	.0058	.0136	.0160
5	.0030	.0102	.0326	.0449
6	.0030	.0028	.0080	.0113
7	.0026	.0073	.0210	.0272
8	.0046	.0181	.0364	.0421
9	.0035	.0078	.0162	.0206
10	.0018	.0042	.0130	.0140
11	.0047	.0089	.0214	.0266
Untreated, painted	.0041	.0194	.0416	.0346
Untreated, unpainted	.0167	.0331	.0738	.1195

[1] All treated sash were painted.

[2] The changes, averaged for 5 specimens, are the differences between the maximum and minimum dimensions observed during the year.

[3] The original dimensions at points 1, 2, 6, and 7 at 12 percent moisture content were about 1.35 inches.

[4] The original dimensions at points 3, 4, and 5 at 12 percent moisture content were about 3.14 inches.

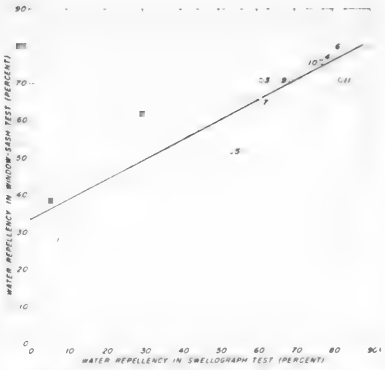

Fig. 6.—Water repellencies of 11 solutions by dimensions at points 3 and 5 (treated, painted test specimens and untreated, painted controls) in the window-sash test during the fourth year of weathering compared with the water repellencies of the solutions in the swellograph test. Five specimens were used for each solution in each test. The numbers refer to the solutions tested.

2 and 6). Changes in width of the bottom rail always exceeded the changes that occurred in the thickness of the stiles.

Because changes in width of the bottom rail at points 3 and 5 were greater than those for any other part of the treated sash, and since the general performance of sash and paint is so largely dependent on their performance near the bottom corner joints, the comparison of the different treating solutions in water-repellent effectiveness was based on the measurements of dimensions at points 3 and 5.

The maximum and minimum deviations in dimensions at points 3 and 5 and in sash weights that occurred from the original measurements of window sash during 4 years of weathering are recorded in Table 4. Figure 4, which illustrates the maximum and minimum deviations in dimensions at points 3 and 5, shows that during the last 3 years, the untreated but painted sash had the greatest swelling from the original dimension (greatest maximum dimension) and also the largest minimum dimension of any of the sash in the study. The measured swelling and shrinking of all sash during this period were analyzed and compared with the computed maximum possible swelling from the original dimension at 12 percent moisture content to the fiber saturation point. This analysis showed that the ends of the untreated but painted rails were swollen to their maximum possible dimension during the wettest periods, but that shrinkage from their maximum dimension was less than for rails treated with preservative number 8 and painted. This indicated that during the wettest periods, the ends of the untreated but painted rails were above the fiber saturation point where no swelling or shrinking occurs with a change in moisture content. This condition was not found in the other sash and it implies that rainwater which entered easily at the untreated joints was trapped in the wood by the paint coating. It is also a logical explanation for the change in dimension of the untreated but painted rails being greatest at midlength rather than at the ends where it was greatest for all other sash.

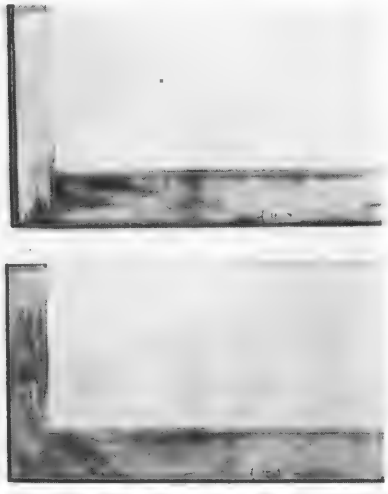

Fig. 7.—The lower left corner of the "indoor" side of untreated window-sash specimens after 4 years of weathering. Upper, with paint and varnish. Lower, without paint and varnish.

Compared with untreated but painted sash, the ends of the rails in the untreated and unpainted sash had less swelling from the original dimension but larger changes from maximum to minimum dimension, presumably because paint was not present to retard the loss of water. In addition, the annual maximum and minimum dimensions at the ends of the untreated and unpainted rails differed from other sash by decreasing with an increase in time. It is believed that the decrease in dimensions was due in part to compression set in the wood during wet periods.

As seen in Figure 4, dipping the sash for 3 minutes in solutions that had high water repellency gave marked stability to the wood near the ends of the bottom rails. The data on maximum and minimum weights of the sash in Table 4 also show that it is very desirable to treat window sash with an effective water repellent. A small difference in the amount of water entering the joints and end grain at the bottom corners of a sash, however, will produce a much greater proportional change in the dimensions of the wood near the joints than in the weight of the entire sash. Because the general performance of sash and paint is so largely dependent on their performance near the bottom corner joints, water repellencies based on dimensions at the ends of the bottom rails (points 3 and 5) are considered more meaningful than those based on weights of the sash.

Dimensions and Weights of Right-Angle Specimens: The changes in dimensions and weights of the right-angle specimens were not always consistent with changes observed in the window-sash specimens. The appearance of the specimens and their changes in dimension and weight indicated that the total effects of the exposure were less severe for the right angles than for the window sash. Figure 8 shows that three coats of paint on untreated wood prevented checking in the angle specimens but not in the sash specimens. For these reasons, and because the sash exposures were more representative of actual use conditions, the original data for changes in dimension and weight of the right-angle specimens are not presented in this report. They were used, however, to calculate water repellencies.

Water Repellencies in Weathering Tests: The true effect of treating millwork, in addition to painting it, is the net effect of the protection offered by the treatment and any beneficial or adverse effect that the treatment may have on the inherent ability of the paint coating to protect the wood. A direct and logical way to determine the effect of treatment is to compare the treated and painted weathering specimens with untreated but painted controls. Therefore, water repellencies for treated and painted specimens were calculated on this basis.

For the calculation of water repellencies in the window sash test, the original dimensions before exposure at 12 percent moisture content at points 3 and 5 on each sash were averaged for the five sash specimens and subtracted from the annual average maximum dimensions at these points. The differences were inserted in the equation of water repellency given previously in this report to obtain the water repellencies for each year of weathering. The change in original weights of the window sash was used in a similar manner to calculate another set of water repellencies for each year of weathering. This procedure also was followed to calculate water repellencies based on dimensions and weights of the right-angle specimens, using the

dimensions at point 3 that occupied a similar position with respect to a corner joint as did points 3 and 5 on the window sash. This procedure for determining water repellency in the weathering tests was considered comparable to the procedure used in the laboratory tests in which the maximum swelling, cupping, or gain in weight for a specified test duration was inserted in the equation of water repellency.

Water repellencies for the treated but unpainted right-angle specimens compared with the untreated and unpainted controls have also been presented (Table 5 and Figure 5) to demonstrate that even in the limited installations where paint will not be applied, it is still desirable to treat exterior millwork with a water repellent or a water-repellent preservative. The advantage of treating millwork with such solutions is demonstrated by the condition of the unpainted right-angle specimens shown in figures 8, 9, and 10.

The water-repellency values for each of the 4 years of weathering for painted sash and right-angle specimens are listed in tables 6 and 7, and values for the fourth year of weathering are shown graphically in Figure 5. It can be seen from Figure 5 that all water repellencies based on dimension were lower than the corresponding values based on weight. In addition, when these values were based on dimension rather than weight, a greater spread occurred between the values of the best and the poorest solutions. In general, the agreement between the water repellencies obtained with painted sash and painted angles was better for the solutions with high water repellencies than those with low.

Relation Between Weathering Tests and Laboratory Tests: The variability in the relative humidity of the test room had a marked effect on the results of the flowing-water test. Therefore, the water repellencies from this laboratory test were not considered in the present comparisons. In addition, the swellometer test, included in the laboratory test program at a late date, was used to test only four solutions. The results indicated that there was excellent agreement between the swellograph and the swellometer tests, but results from tests of more solutions by the swellometer method are needed for comparison with the weathering tests.

Water repellencies for the 11 solutions in the five remaining laboratory tests were compared for correlation with their water repellencies based on maximum dimension in the window-sash test for the fourth year of weathering. Water repellencies were calculated from data taken at several times during three of the laboratory tests (water spray, weight gain at 30 to 80 percent relative humidity, and weight gain at 65 to 97 percent rela-

Table 4.—MAXIMUM AND MINIMUM MEASUREMENTS OF DIMENSIONS AT POINTS 3 AND 5 AND OF WEIGHTS OF WINDOW SASH DURING 4 YEARS OF WEATHERING

Solution number[1]	Measurement	Deviation from original dimension[2] [3]				Deviation from original weight[2] [4]			
		1957 Inch	1958 Inch	1959 Inch	1960 Inch	1957 G.	1958 G.	1959 G.	1960 G.
1	Maximum	0.0737	0.0656	0.0806	0.0726	76	79	155	213
	Minimum	.0027	.0122	.0461	.0405	—15	—11	47	45
2	Maximum	.0186	.0172	.0362	.0386	32	28	67	88
	Minimum	—.0091	—.0068	.0130	.0106	—22	1	28	14
3	Maximum	.0212	.0151	.0280	.0292	37	25	58	64
	Minimum	—.0062	—.0010	.0141	.0007	—17	—14	28	17
4	Maximum	.0165	.0123	.0247	.0231	31	18	50	58
	Minimum	—.0068	—.0048	.0120	.0071	—18	—17	20	9
5	Maximum	.0182	.0195	.0471	.0481	31	24	71	92
	Minimum	—.0123	—.0109	.0130	.0032	—22	—22	27	15
6	Maximum	.0171	.0102	.0225	.0198	30	12	38	34
	Minimum	—.0037	—.0007	.0099	.0085	—10	—9	15	10
7	Maximum	.0203	.0144	.0317	.0342	31	20	53	68
	Minimum	—.0062	—.0040	.0136	.0070	—19	—19	21	10
8	Maximum	.0943	.0652	.0731	.0640	113	91	143	174
	Minimum	.0211	.0070	.0282	.0219	—4	—8	42	23
9	Maximum	.0132	.0115	.0271	.0289	28	17	62	80
	Minimum	—.0088	—.0052	.0129	.0083	—20	—18	23	14
10	Maximum	.0157	.0105	.0238	.0244	28	15	54	60
	Minimum	—.0074	—.0041	.0113	.0104	—18	—13	20	14
11	Maximum	.0167	.0156	.0298	.0296	32	20	57	71
	Minimum	—.0048	—.0015	.0123	.0030	—19	—17	24	14
Untreated, painted	Maximum	.0933	.1037	.1046	.1011	206	219	414	438
	Minimum	.0187	.0652	.0806	.0665	—10	39	49	35
Untreated, unpainted	Maximum	.0470	.0311	.0356	.0168	142	153	246	380
	Minimum	—.0619	—.0677	—.0498	—.1026	—38	—57	—32	—126

[1] All treated sash were painted.
[2] The deviations are averages of 5 specimens.
[3] The original dimensions at points 3 and 5 were about 3.14 inches at 12 percent moisture content.
[4] The original average weight of wood at 12 percent moisture content in a sash, obtained by averaging the weights of the 5 sash in each of the 13 sets, ranged from 1,925 to 2,035 grams.

Table 5.—WATER-REPELLENCY VALUES FOR TREATED BUT UNPAINTED RIGHT-ANGLE SPECIMENS BASED ON DIMENSION AND WEIGHT DURING 4 YEARS OF WEATHERING

Solution number	Water repellency [1]							
	By dimension				By weight			
	1957 Percent	1958 Percent	1959 Percent	1960 Percent	1957 Percent	1958 Percent	1959 Percent	1960 Percent
1	22	28	27	—21	55	65	52	49
2	52	73	63	25	76	82	80	79
3	63	85	82	64	81	87	85	89
4	69	90	85	74	84	89	87	92
5	42	56	23	—15	76	82	69	76
6	78	94	93	93	87	92	91	95
7	68	91	87	76	83	89	85	89
8	0	17	15	—19	48	65	58	62
9	52	74	60	26	81	88	83	84
10	71	89	84	70	86	90	86	88
11	68	88	80	65	82	88	85	88

[1]Water repellency calculated by method described in this report.

Table 6.—WATER-REPELLENCY VALUES BASED ON DIMENSION AND WEIGHT DURING 4 YEARS OF WEATHERING OF TREATED AND PAINTED WINDOW SASH

Solution number	Water repellency [1]							
	By dimension				By weight			
	1957 Percent	1958 Percent	1959 Percent	1960 Percent	1957 Percent	1958 Percent	1959 Percent	1960 Percent
1	21	37	23	28	63	64	62	51
2	80	83	65	62	84	87	84	80
3	77	85	73	71	82	89	86	85
4	82	88	76	77	85	92	88	87
5	80	81	55	52	85	89	83	79
6	82	90	78	80	86	95	91	92
7	78	86	70	66	85	91	87	84
8	—1	37	30	37	45	58	66	60
9	86	89	74	71	86	92	85	82
10	83	90	77	76	86	93	87	86
11	82	85	72	71	85	91	86	84

[1]Water repellency calculated by method described in this report.

Table 7.—WATER-REPELLENCY VALUES BASED ON DIMENSION AND WEIGHT DURING 4 YEARS OF WEATHERING OF TREATED AND PAINTED RIGHT-ANGLE SPECIMENS

Solution number	Water repellency [1]							
	By dimension				By weight			
	1957 Percent	1958 Percent	1959 Percent	1960 Percent	1957 Percent	1958 Percent	1959 Percent	1960 Percent
1	42	49	51	42	30	21	56	58
2	70	69	68	70	45	34	66	73
3	66	67	76	78	61	52	80	85
4	70	70	78	80	56	45	77	82
5	44	50	63	66	26	24	66	72
6	71	71	77	78	65	59	81	86
7	62	64	73	77	53	47	75	82
8	50	54	34	18	12	22	22	39
9	60	62	67	70	53	45	74	79
10	57	62	75	75	60	48	79	83
11	60	63	69	73	50	45	72	80

[1]Water repellency calculated by method described in this report.

tive humidity). The set of water-repellency values from each of these tests which agreed best with the window sash test was selected by inspecting the plotted comparisons. These optimum test exposure times are shown in Table 8. Only one set of values was obtained from the swellograph and cupping tests.

In the window-sash test, specimens were exposed to both liquid water (rain) and water vapor. In the laboratory tests, however, specimens were exposed to either liquid or vapor. For this reason, an effort was made to combine two of the laboratory tests, one that exposed specimens to liquid water and the other that exposed specimens to water vapor, with results that when averaged would correlate better with the window sash test. The two most promising combinations, selected by inspecting plotted data, were included in the comparisons (Table 8).

The degree of correlation between weathering and laboratory tests was determined from computed correlation coefficients. This coefficient varies from -1 to $+1$ and is independent of any units of measurement. As the correlation coefficient approaches 1 numerically, the scatter of plotted points about a straight line decreases. When it equals 1 numerically, all points are on a straight line and the correlation is perfect. The sign of the coefficient indicates whether the line has a negative or positive slope.

The correlation coefficients are given in Table 8. When compared with the window-sash test, the swellograph test had a coefficient of 0.922 and the test for weight gain at 65 to 97 percent relative humidity had a coefficient of 0.814. The coefficient of 0.814 is considered to be significantly lower than 0.922 for the number of solutions compared. The correlation coefficients for the other comparisons in Table 8 range from 0.872 to 0.939 and are not considered to be significantly better or worse than the coefficient for the swellograph (present NWMA standard).

The water repellencies based on dimensions from the window-sash test during the fourth year of weathering and from the swellograph test are compared in Figure 6. The figure shows that the seven solutions that had water repellencies above 60 percent in the swellograph test also had repellency values above 60 percent in the window-sash test. Except for water-repellent preservative number 2, solutions that had repellency values below 60 percent in the swellograph test had water repellencies below 60 percent in the window-sash test. This same rela-

Fig. 8.—Untreated specimens after 4 years of weathering. The bottom faces of the five right-angle specimens are shown in the normally glassed area of the lower right quadrant of the "outdoor" side of a window sash. Upper, unpainted. Lower, painted.

Fig. 9.—Treated specimens after 4 years of weathering. The bottom faces of the five unpainted right-angle specimens are shown in the normally glassed area of the lower right quadrant of the unpainted "outdoor" side of a window sash. Upper, treated with solution number 8, a good preservative. Lower, treated with solution number 10, a good water repellent.

Fig. 10.—Treated specimens after 4 years' weathering. The bottom faces of the five unpainted right-angle specimens are shown in the normally glassed area of the lower right quadrant of the painted "outdoor" side of a window sash. Upper, treated with solution number 1, a poor water-repellent preservative. Lower, treated with solution number 6, a good water-repellent preservative.

tion was found when the water repellencies from the window-sash test were compared with those from the water-spray test after the second spray. It was not found, however, when the repellencies from the window-sash test were compared with those from the other single or combined laboratory tests listed in Table 8.

It then appears that a 3-minute dip in a solution with a water repellency of 60 percent or better in the swellograph test will give good protection for 4 years to painted window sash. There is evidence, however, that the repellency of many of the solutions may be decreasing with increasing weather exposure. The apparent change in water repellency during weathering may also be due in part to such factors as variation in the weather and the trapping of water in the wood by the paint, and suggests the need for continuing the study to establish the durability of the solutions in test.

Appearance of Window Sash: After 4 years of weathering, the window sash were inspected for paint integrity, putty cracks, wood checks and splits, rust, stain, and decay. The results of the inspection are given in Table 9. Figures 7 through 10 show the appearance of some of the sash after 4 years of weathering.

Paint Integrity: In comparison with that of the untreated but painted sash, the integrity of the paint on the treated sash was poorer for those treated with preservative number 8, and better for those treated with the remaining solutions.

Putty Cracks: The condition of the putty on all treated and painted sash was better than that on the untreated but painted sash.

Wood Checks and Splits: In comparison with that of the untreated but painted sash, the severity of the checking and splitting of the treated and painted sash was greater for those treated with water-repellent preservatives numbers 5 and 1, and less for those treated with the remaining solutions.

Stain and Decay: The stain recorded in the inspection appeared to be caused by stain or decay fungi. The only treated sash that was stained on the "outdoor" side was one treated with water-repellent preservative number 1. The stain was about equal in severity to the stains on the five untreated but painted sash. On the "indoor" side,

Table 8.—CORRELATION COEFFICIENTS FOR WATER REPELLENCIES IN THE WINDOW-SASH TEST COMPARED WITH WATER REPELLENCIES IN LABORATORY TESTS[1]

Test number	Name of test	Laboratory test: Water or water vapor exposure	Laboratory test: Test duration Hr.	Correlation coefficient
1	Swellograph	Water	½	0.922
2	Water spray[2]	do	½	.932
3	Cupping	Vapor	13	.872
4	Weight gain, 30 to 80 percent relative humidity	do	24	.895
5	Weight gain, 65 to 97 percent relative humidity	do	24	.814
—	Average, tests Nos. 1 and 5	Water and vapor	½ and 24	.923
—	Average, tests Nos. 2 and 5	do	½ and 24	.939

[1]Water repellencies in the window-sash test were based on maximum dimensions at the ends of the bottom rail (points 3 and 5) for the 4th year of weathering. Eleven solutions were tested by each method.

[2]Water repellency calculated from swelling after the second spray.

Table 9.—SOME FACTORS AFFECTING THE APPEARANCE OF WINDOW SASH AFTER 4 YEARS OF WEATHERING

Solution number	Ratings of appearance [1]					
	"Outdoor" side					"Indoor" side
	Paint integrity	Putty cracks	Wood checks and splits	Stain [2]	Rust [3]	Stain [2]
1	2.8	6.6	6.8	2.2 (1)	1.4 (2)	3.0 (3)
2	2.0	4.2	3.4	1.0	1.0	1.0
3	1.8	3.0	3.0	1.0	1.0	1.0
4	1.4	4.0	4.0	1.0	1.0	1.0
5	2.6	3.4	6.2	1.0	1.0	1.0
6	2.0	2.0	2.2	1.0	1.0	1.0
7	1.8	2.8	4.2	1.0	1.0	1.0
8	4.0	6.0	5.4	1.0	8.0 (5)	3.6 (5)
9	1.8	2.0	3.4	1.0	1.0	1.0
10	1.6	3.4	3.4	1.0	1.0	1.0
11	3.2	3.2	3.8	1.0	1.0	1.0
Untreated, painted	3.6	7.2	6.0	6.4 (5)	2.8 (3)	8.0 (5)
Untreated, unpainted	---	8.4	8.0	5.8 (5)	------	8.4 (5)

[1]Average of 5 specimens based on a scale of from 1 (good) to 10 (bad). Numbers in parenthesis following ratings of stain and rust indicate the number of sash affected.
[2]The stain recorded appeared to result from stain or decay fungi. Decay was present in all untreated sash.
[3]Rusting occurred over the steel dowels in the corner joints at the bottom of the sash.

stain could be seen on three sash treated with water-repellent preservative number 1 and on five sash treated with preservative number 8. The staining on the treated sash was much less severe than that on the 10 untreated sash. Probing all stained sash with a knife blade revealed that decay had softened the wood near the bottom corner joints of the 10 untreated sash.

Rust: Rust could be seen in the paint on the "outdoor" side of the five sash treated with preservative number 8, two sash treated with water-repellent preservative number 1, and three untreated but painted sash. It was most severe on the specimens treated with solution number 8 and least severe on the specimens treated with solution number 1. The rust appeared over the steel dowels in the bottom corner joints.

Conclusions

Correlation with the water repellencies obtained from dimensions in the window-sash test during the fourth year of weathering was about equally good for the repellencies obtained in four laboratory tests and two combinations of laboratory tests. The single tests included the swellograph (present NWMA standard), water spray, cupping, and weight gain at 30 to 80 percent relative humidity. The two combinations were the average of the weight-gain test at 65 to 97 percent relative humidity with the swellograph test and with the water-spray test. Correlation of repellency values of the window-sash test with those of the weight-gain test at 65 to 97 percent relative humidity test was significantly poorer.

Results show that a 3-minute dip in a solution with a water repellency of 60 percent or higher in the swellograph test will give good protection in service to painted window sash. The data indicated, however, that the water repellency of many of the solutions tested may be decreasing with increasing weather exposure, suggesting the need for continuing the study to establish the durability of the solutions in test.

The dimensions of the painted window sash during weathering indicated that rain water entered the bottom corner joints and end grain of sash that were untreated or treated with solutions low in water repellency, moved through the wood away from the point of entry, and then was trapped in the wood by the paint. The entrance of troublesome amounts of water was prevented by a 3-minute dip of the sash in a good water repellent or water-repellent preservative. The measurements and observations of the weathered sash did not indicate a preference for one of these two types of solutions, but they did show that treatment with either type was more beneficial than treatment with a preservative only.

The shrinking and swelling that were observed during weathering of the window sash were analyzed and compared with the total swelling theoretically possible. The comparisons indicated that during the wettest periods of the last 3 years of weathering, the moisture content of the wood near the ends of the bottom rails in the untreated but painted sash was greater than the fiber saturation point (about 30 percent) above which no shrinking or swelling occurs. This condition did not exist at the other points where dimensions were measured on the untreated but painted sash, nor at any of the points on the untreated and unpainted or treated and painted sash.

To evaluate the protection given to window sash by treating solutions, water repellencies based on dimensions near the bottom corner joints are more indicative of effectiveness than those based on dimensions at points not adjacent to a bottom corner joint or on the weight of the entire specimen.

The window-sash test is more typical of service conditions and is considered better than the right-angle specimen test for evaluating solutions for the treatment of exterior millwork.

Performance during 4 years of weathering showed that treatment with a good water repellent or water-repellent preservative reduced considerably the shrinking, swelling, and end checking of wood members of unpainted angle specimens.

The results obtained from window-sash specimens exposed to the weather at Madison for 4 years show that a 3-minute dip of window sash in a good water repellent or water-repellent preservative before painting will reduce or eliminate stain and decay fungi, end checking, cracking of the glazing compound, excessive swelling, and premature paint failure.

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Dimensional Stability of Oak Flake Board

. . . as affected by particle geometry and resin spread[1]

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Thin flakes and high resin spreads give a board with good thickness stability properties. Equilibrium moisture content was increased by increases in resin spread while thickness changes were limited. Unassembled flakes that had the resin treatment also equalized at a higher equilibrium moisture content in adsorption than either the dried or freshly cut flakes.

MANY STUDIES HAVE BEEN made of the various effects of particle geometry on the physical and mechanical properties of board made of these particles and all have agreed that the shape, dimensions, orientation in the product, fiber orientation in the particle, and resin distribution have an important bearing on the dimensional stability (1, 2, 3, 5, 7, 11). Board made of scarlet oak flakes, which had also been studied by Post (10), was investigated to determine the effect of the particle geometry and resin content on dimensional changes in the material.

Dimensional changes are the result of fluctuations in board moisture content, the moisture content changes having been produced by variations in relative humidity. The magnitude of these dimensional changes is altered by the size of the component flakes and the quantity of nonhygroscopic resin included for bonding. Springback, a type of dimensional change characteristic of particle boards, occurs upon release of compressive forces induced in the board during manufacture. A fluctuating humidity is the most likely triggering action for the release of these forces. It was thought that the thermal treatment of the components and the board, in addition to the resin content, would affect the dimensional changes and the equilibrium moisture content. Provisions were made in the design to study these factors.

Procedure

The boards in this study contained 3.27, 6.54, and 13.07 grams of resin solids per square meter. Panels were composed of flakes that were 0.006, 0.012, 0.025, and 0.050 inch thick, and flake lengths of 0.5, 1, 2, and 4 inches. These sizes encompass those used in commercial operations and should be investigated from the standpoint of improving certain board properties at the extremes of the particle dimensions and resin content ranges

[1] Presented at the 1961 Annual Meeting of the Forest Products Research Society, Louisville, Ky., Session 5, Division 5 (Particle and Fiber Processes A), June 20, 1961.

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FLAKE LENGTH INCHES	RESIN SPREAD															
	3.27 G/M²					6.54 G/M²					13.07 G/M²					
	FLAKE THICKNESS - INCHES															
	.006	.012	.025	.050		.006	.012	.025	.050		.006	.012	.025	.050		
0.5																
1																
2																
4																

Fig. 1.—The experimental design, the result of variables, of this study is shown.

that are common to industrial enterprises. These variables resulted in the experimental design given in Figure 1, permitting the use of the analysis of variance technique to determine the effect of any of the three main variables and their interactions.

In addition to the main part of this study on thickness dimensional changes at different equilibrium moisture contents, work was done to determine the moisture content differences between outer and inner parts of the conditioned samples. Individual flakes from various stages of the production process were also examined. Similar designs permitted statistical analysis of these complementary studies.

All conditioning of the specimens was carried out at 90° F. A drying oven pressure filled with calcium chloride dried air was used as the starting point, with a relative humidity of 15 percent and equilibrium moisture content of 3.3 percent. Saturated salt solutions were used for the 21, 83, and 92 percent relative humidities. Each atmosphere was checked constantly by the technique described by Higgins (4). Equilibrium moisture contents for these humidities are close to 4.50, 16.80, and 21.30 percent. The 50 percent relative humidity was conditioned in a cabinet made especially for this procedure; equilibrium moisture content was 9.00 percent. All sample weighing was to the nearest 0.001 gram. The specimens had an oven dry weight range of 31.841 to 44.414 grams, with the average 37.941 grams. A change in weight of 0.050 grams meant a change in moisture content of 0.133 percent in the average specimen. Specimens were considered to have reached constant weight when the fluctuating weight over a 24-hour period was less than ±0.050 gram, the permissable fluctuation in moisture content being about 0.266 percent. These maximums were never reached, the variation being about ±0.020 gram and less. In flakes, the fluctuations were held to ±0.010 gram, and in the face-core specimens to ±0.015 gram. Calculations for equilibrium moisture content of each specimen at each humidity in adsorption and desorption were made by the formula:

$$\text{e.m.c.}(\%) = 100 \times \frac{\text{equilibrium weight} - \text{oven-dry weight}}{\text{oven-dry weight}}$$

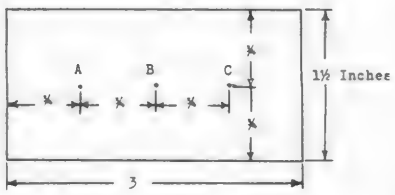

Fig. 2.—Dimensional stability specimen is shown; A, B, and C are locations for thickness measurements.

Three thickness measurements were made on each specimen (Figure 2) at each equilibrium condition and averaged. Using the thickness for the respective specimen at 15 percent relative humidity as a base, the percent thickness change was equal to:

$$100 \times \frac{\text{(average thickness at equilibrium)} - \text{(average thickness at 15\% relative humidity)}}{\text{average thickness at 15\% relative humidity}}$$

It was intended originally by Post (10) that all boards would be manufactured to essentially the same specific gravity, but tests showed that considerable variation existed among boards and even within a single board. Klauditz (5) and Miller (9) have shown that the dimensional changes that take place in a particle board are influenced to some extent by specific gravity, the relationship taking the form of a straight line. Since complete replication of this study was not possible, the effects of specific gravity could not be corrected statistically and the assumption was made that a single linear relationship existed between specific gravity and thickness swell properties for all resin contents and flake dimensions. At 21 and 50 percent humidity conditions in adsorption, a straight line fitted to relative thickness change plotted against specific gravity gave a negative slope significantly different from zero. Each value of relative thickness change (r.t.c.) was corrected to the average specific gravity (0.67479) of the specimens studied by the following:

$$\text{Corrected r.t.c.} = \text{r.t.c.} - (\text{slope})(\text{specific gravity} - 0.67479)$$

This negative slope is different from the results found by other investigators (5, 9). A possible explanation is that this high specific gravity board has better bonds through closer mating of particles. The dimensional changes that take place at the lower relative humidities are not sufficient to weaken these bonds and permit the greater swelling expected. Findings relative to the adhesive distribution in these samples are found in another report (Jorgensen and Murphy, to be published).

Reports have indicated that improved stability can be given to the thickness dimension of a board by decreasing the thickness of the component flakes (1, 5). The water immersion test has commonly been used to determine the stability of flake boards instead of conditioning in controlled atmospheres as was done in the present study.

Present Findings

Figures 3 and 4 show that, up to an equilibrium moisture content of about 15 percent, flake thickness has very little effect on stability and that the great effect of flake thickness is only between 16 and 21 percent equilibrium moisture content. Figures 5 and 6 show the effects of resin spread and flake length on thickness change, and it is quite clear that flake thickness has a much more important effect than either of these. From a practical standpoint, it appears that any board which will not be subjected to conditions above 16 percent equilibrium moisture content can be manufactured with thicker flakes. Thickness dimensional

changes will be no more of a problem than if thinner, more expensive particles were used. If higher equilibrium moisture content conditions are to be encountered, it is clear that the thinner flakes and higher resin spreads will produce the most stable product.

The unrecoverable thickness expansion known as springback has been shown in these same Figures to consistently occur between 16 and 21 percent equilibrium moisture content in the board studied. We are now checking other boards to discover if this range is consistent. Judging by the rate of thickness expansion in this range it appears that the compressive stresses instilled in the board during manufacture have continued to build up during adsorption to the point where bond breakdown occurs and the forces are released. From the desorption curves it is evident that this thickness expansion is not recoverable, however, attention should be called to the parallelism between the adsorption and desorption curves between 15 and 83 percent relative humidity. Mechanical tests of these boards were not possible after conditioning, but visual examination of many specimens failed to reveal defects which might affect the strength properties. Such testing must be done first, but it is suggested that boards to be used where there is any possibility of equilibrium moisture content conditions going above 16 percent, such as in floor underlayment, be conditioned to the point where springback occurs before sale. Such board could be guaranteed to change in thickness only the small amount represented by the desorption curves in Figures 4 to 6.

Figure 7 is a graphic presentation of one of the results of this study which is not understood, but it occurred with such consistency in the boards and the resin sprayed flakes studied that it must be reported. In all but four cases (0.012- and 0.025-inch flakes, 4 inches long at 50 percent relative humidity; 0.006-inch flakes, 2 inches long, 92 percent relative humidity; and 0.025-inch flakes, 4 inches long 92 percent relative humidity) the 6.54-gram spread equalized lower than the 3.27-gram spread and both of these were lower than the heavy 13.07-gram spread. If the bonding of wood particles is similar in many aspects to conventional gluing as suggested by Marian (6) then the hydrogen bonds assumed to be tied to the resin would not be free for any surface-absorbed water. Therefore the resulting equilibrium moisture content would be low. Thicker flakes might be expected to produce higher equilibrium moisture contents than thinner flakes in view of the reduction in surface area in contact with the resin and the lower percentage of hydrogen bonds involved. This was not true here, however. Although the high spread specimens generally equalized at higher moisture contents, they were at the same time more dimensionally stable than specimens of lower spreads at the 83 percent and 92 percent relative humidity conditions.

In the study of the equilibrium moisture content variations thruout the panel thickness, it was conclusively shown that the core position equalizes at a higher moisture content than the face positions during initial adsorption. There is no significant difference in equilibrium moisture contents, however, between the two panel positions in desorption. The lower equilibrium moisture content of the panel face is attributed to the high temperature of the press platens which come in contact with the panel surfaces during pressing. Previous work (8, 12) has shown that thermal treatment of cellulosic material has an effect on equilibrium moisture content. Apparently this loss of hygroscopicity is somewhat recovered under the 92 percent humidity conditions for, although there was

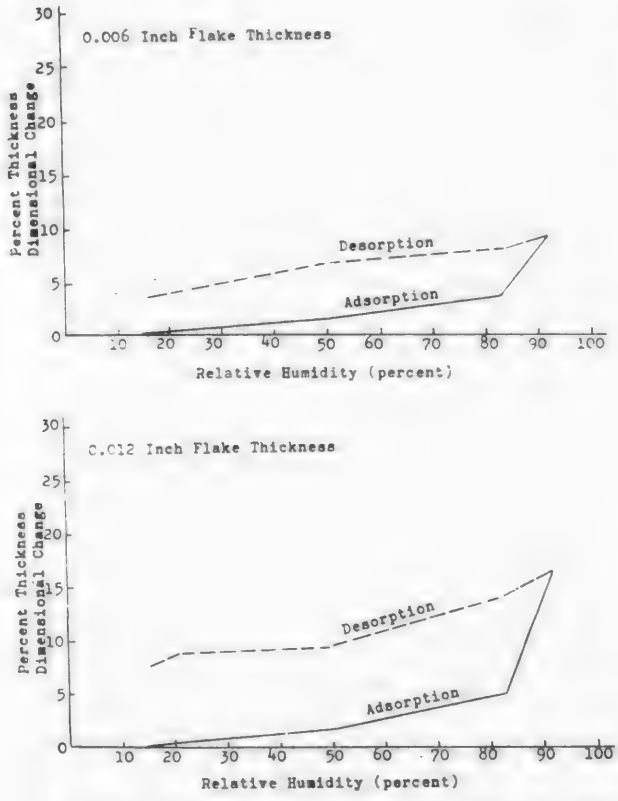

Fig. 3.—Plots indicating the effect of flake thickness on the percent thickness dimensional change of the low resin spread, 0.5-inch flake length specimens, are shown.

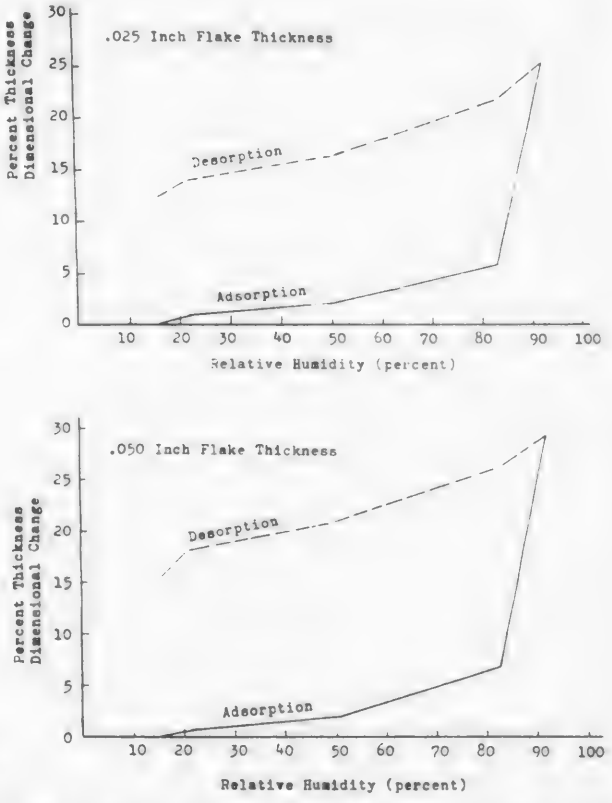

Fig. 4.—Plots indicating the effect of flake thickness on the percent thickness dimensional change of the low resin spread, 0.5-inch flake length specimens, are shown.

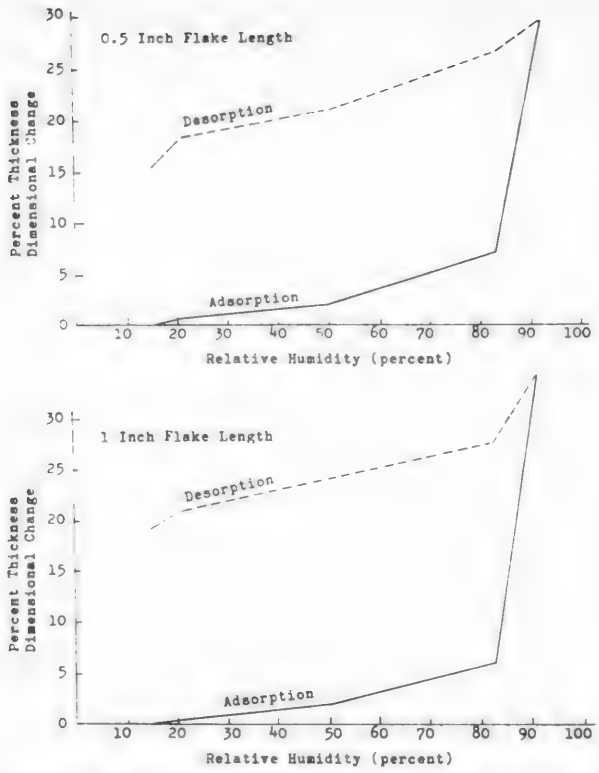

Fig. 5.—Plots indicating percent thickness dimensional change of thick flakes at the low resin spread are shown.

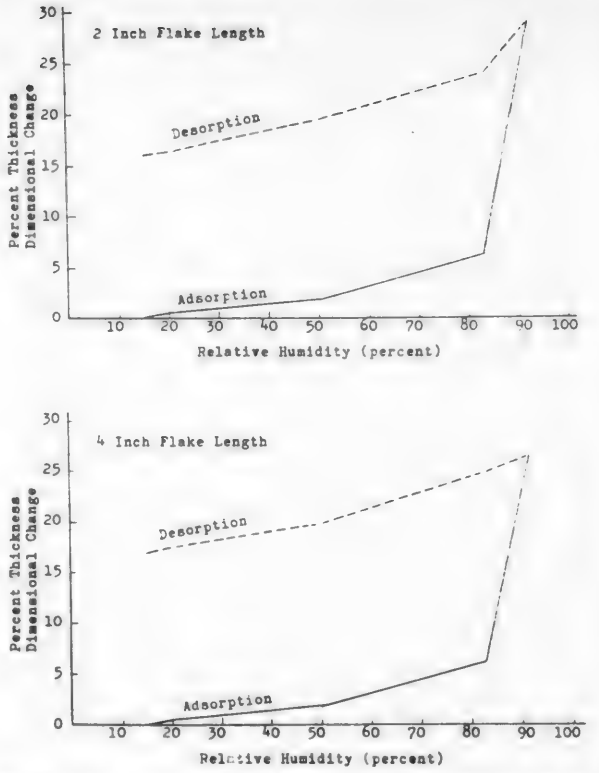

Fig. 6.—Plots indicating the percent thickness dimensional change of thick flakes at the low resin spread are shown.

still a small difference in equilibrium moisture contents, it was not statistically significant.

The thermal effect previously mentioned was confirmed in the flake portion of the study where the dried flakes equalized at a lower equilibrium moisture content than the non-dried. Recovery after the 92 percent humidity conditioning was similar.

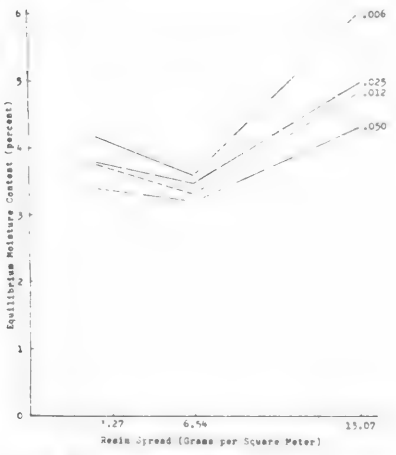

Fig. 7.—Shown is the effect of resin spread and flake thickness on the equilibrium moisture content of the 0.5-inch flake length specimens conditioned in initial desorption at 15 percent relative humidity.

Evaluation of Results

Results of this study are of value in that they indicate equilibrium moisture contents reached by various size particles and various resin spreads at controlled humidity conditions. The dimensional changes in adsorption and desorption are shown to be negligible up to 14 to 20 percent equilibrium moisture content. Dimensional changes beyond 83 percent relative humidity, at 90° F., are extreme, apparently due to complete release of internal forces inherent in the compressed mass of wood particles, known as springback.

We consider these studies far from complete. In addition to exploring those unknowns already mentioned in this paper, we hope to study other resin spreads in an effort to locate those resulting in lowest equilibrium moisture contents and clarify the work on the flake length problem.

Literature Cited

1. Brumbaugh, J. 1960. Effect of flake dimensions on properties of particle boards. For. Prod. Jour. 10:243–246, May.
2. Clark, James d'A. 1955. A new dry process multi-ply board. For Prod. Jour. 5:209–213, August.
3. Heebink, B. G., and R. A. Hann. 1959. Stability and strength of oak particle boards. For. Prod. Jour. 9:197–203, July.
4. Higgins, N. C. 1955. The equilibrium moisture content-relative humidity relationship of selected native and foreign hardwoods. Unpublished thesis. The Pennsylvania State University, University Park, Pa. August.
5. Johnson E. S. (ed.). 1956. Wood particle board handbook. The Industrial Experimental Program of the School of Engineering, North Carolina State College, Raleigh, N. C.
6. Marian, J. E. 1958. Adhesive and adhesion problems in particle board production. For. Prod. Jour. 8:172–176, June.
7. Marra, G. G. 1954. Discussion following article by Turner. For. Prod. Jour. 4:210–223, October.
8. MacLean, J. D. 1945. Effect of heat on the properties and serviceability of wood, experiments on thin wood specimens. U. S. For. Prod. Lab. Rept. No. R1471.
9. Miller, H. C. L. 1953. Chipcore—its characteristics and production. For. Prod. Jour. 3:149–152, December.
10. Post, P. W. 1961. The effect of particle geometry and resin content on the physical and mechanical properties of oak flake board. For. Prod. Jour. 11:34–37, January.
11. Turner, H. D. 1954. Effect of particle size and shape on strength and dimensional stability of resin-bonded wood particle panels. For. Prod. Jour. 4:210–223, October.
12. Wise, L. E., and E. C. Jahn (eds.) 1952. Wood chemistry. A.C.S. Monograph series 97. Reinhold Publishing Co., New York.

Economics of Machine Replacement[1]

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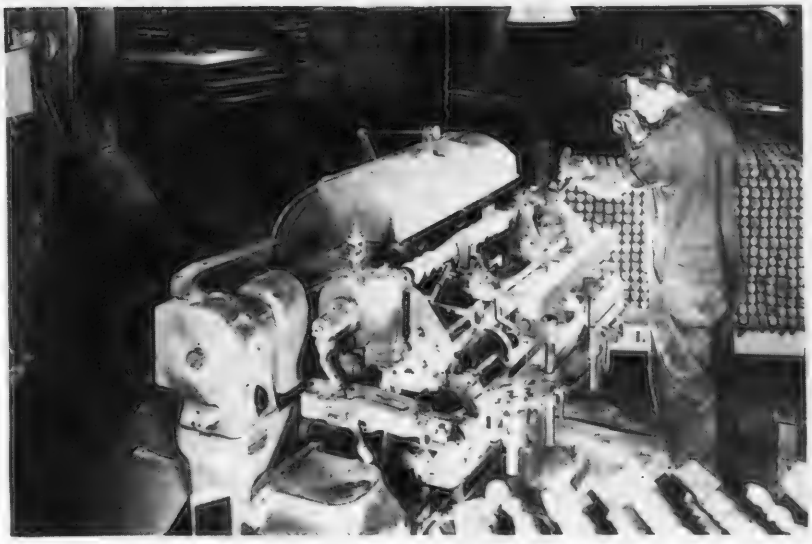

The economics of machine replacement involve more than just whether a machine should be replaced and how much it will cost. Theoretical considerations, physical and mental limitations of personnel, displacement or interruption of production, the new machine in regard to plant layout, and the monetary cost must be considered. This study relates all these factors to the matter of machine replacement.

THE ECONOMICS OF MACHINE REPLACEMENT is not merely a matter of whether a machine needs replacing and how many dollars it costs. It involves the theoretical considerations, physical and mental limitations of personnel, displacement or interruption of production, the new machine in regard to plant layout, and, of major importance, the monetary cost. Although it would be impossible to discuss in detail each of these various phases in the time allotted, examples will illustrate how each of these items is important in the matter of machine replacement.

Types of Machine Replacement

Generally there are three types of machine replacement, which can be broken down as follows. There are many times when simple replacement of a new machine for an old machine is made. In this case, the new machine would be exactly like the old machine and would do the same job as the old machine. It would not have any new features or attachments to improve the machine. It would simply be a replacement of a new machine for an existing one which has worn to the point where breakdowns and inaccurate work, or both, require it to be replaced.

Another type of replacement is that of obsolescense. An example of this is a moulder of the old type used in many plants today. The new moulders such as those with tapered spindles allow much faster running speeds and facilitate quick setups; consequently, more production can be obtained through this type machine. In this case the old moulder would be obsolete, however, the replacement would be a moulder for a moulder.

The third and probably the most important type of machine replacement would be that of the substitution of a production type machine using new methods in lieu of old machines and old methods. One of the most striking examples of this is the case of the European Continuous Feed Veneer Edge Bander which was introduced into this country several years ago. This machine proved to be a highly efficient way in gluing on veneer edge bands, and, in many high production plants, the machine using three men could do the work formerly done by seven to nine men in the veneer edgebanding department.

When considering any one of the three types of replacement, there are many questions which must be answered. In the case of the simple replacement of a new machine for an old one of the same type, the question should be asked whether or not this

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machine is doing the job satisfactorily and economically? Does it have the production capacity required for the particular operation? Have there been instances where a better product could have been made or jobs done on this machine which have to be done elsewhere as additional handling? If the answer to the last question is doubtful, then probably this type of replacement is not the one for this operation. A complete investigation should be made as to whether or not a different type machine should be purchased as replacement for this old machine.

Many of the same questions arise in the case of obsolescence. It may be possible that the present machine could simply be modified to overcome the obsolescence caused by newer models. If the machine is mechanically all right, it might be economical to have it modified to do the jobs of newer machines. If it has been determined that new attachments and improvements of machines are needed for a particular product, then the replacement could be determined as one of obsolescence. In the past several years the term "obsolescence" is one which has been greatly over-used. However, in many furniture factories, it is obvious that the word "obsolescence" is not over-used. Today, many factories have a machine or machines which would do a better job if modified or replaced by new machines of the same type.

Estimate Costs

In order that the complete financial picture be obtained, it is desirable to make as accurate an estimate as possible for all costs involved. The best way to make sure all factors are included is to have a check list against which all items can be estimated. Economy studies can then be made of all contemplated machinery replacements and additions.

Most plants receive suggestions and requests regularly from employees and supervisors in relation to their individual projects. However, if economy studies are made using the same procedure for all, then it can be determined mathematically which investments will yield the best return for the plant.

Many plants use a minimum return figure, for example 15 percent, that an investment must return before it is considered. Another method used is the establishment of the priority list using economy studies to determine returns. Naturally, in most cases the highest return investment would be made first and lower return investments to follow. There always exist exceptions to every rule, however, and there may be cases where a relatively low investment return rate item might have to be purchased over a higher one. One example of this might be when a machine in use would be a safety hazard. How can this factor always be measured in dollars and cents? Such a case would depend entirely on local situations.

It must be pointed out that any study of this type is only as accurate as the estimates used in arriving at the individual costs. It is imperative that the estimates be as accurate as possible, regardless of what formula is used in determining the economic results of machine replacement.

Check List: Several items should be included on a check list for economic studies. Such a list will vary from plant to plant, however, a basis for sound economic studies can be formed from the following:

- Investment
- Expected economic life in years (or capital recovery period specified by management to be used for economy studies)
- Estimated salvage value at end of life
- Annual cost of taxes
- Annual cost of material
- Annual cost of insurance
- Annual cost of direct labor
- Annual cost of indirect labor
- Annual cost of maintenance and repairs
- Annual cost of power
- Annual cost of supplies and lubricants
- Annual cost associated with space occupied by machines
- Other annual indirect costs

Hand Shaper vs. Automatic

For example, if a furniture manufacturer plans to purchase machinery to be used in the production of office chairs, he must decide between hand shapers and automatic shapers. Data on the performance of these machines are available from another plant owned by the manufacturer. For the contemplated operations, it appears necessary to buy either two hand shapers or one automatic shaper.

Investment estimates—$7,700 for an automatic shaper, and $2,550 each for hand shapers—are based on manufacturers' quotations plus estimates of freight and installation costs. The economic life assumed for each—5 years—is based on an arbitrary judgment by the management as to the desired capital recovery period in view of possible obsolescence or changing conditions of demand. This is in spite of the likelihood that these machines would be physically serviceable for 20 years or more. Any prospective salvage value at the end of the 5-year period is to be neglected in the economy study.

The annual tax rate—1.8 percent—is a matter of record which is determined from the past years' tax bills and the ratio of assessed valuation to book value of plant. Similarly, the insurance rate—0.7 percent—is a matter of record, determinable by inspection of fire insurance policies. Experience indicates that material cost is not affected by the type of shaper used. (This would be an item for consideration if spoilage were greater on one than on the other.)

Direct labor cost estimates are based on time studies, estimated annual production, and estimated wage rates. On the basis of time studies on the production of chair seats, legs, posts, and spindles, it is estimated that under the average conditions of production the total time for producing the necessary parts for a chair (taking into account setup times and assuming the production of parts in lots of the most economic size) will be 8.62 minutes on a hand shaper, and 4.72 minutes on an automatic shaper. Total annual chair production is estimated as 20,000. Skilled labor at $2.10 per hour will be required with hand shapers, whereas the operator of an automatic shaper is less skilled and will be paid $1.70 per hour. These rates include labor extras. An examination of the duties of the various factory employees classified under "indirect labor" (for instance, foremen, crane operators, truckmen, cost clerks, janitors) leads to the conclusion that this item will be unaffected by the choice.

Estimates of annual cost of maintenance and repairs—$60 for each hand shaper and $40 for the automatic—are used on average charges for somewhat similar machines used on other operations. Average power consumption of each hand shaper will be 3 kilowatts, of the automatic 10 kilowatts; the average cost of purchased electric energy is 2.5 cents per kilowatt hour. Annual supplies and lubricants are estimated as $5 per machine.

Space charges (based on investment charges on land and building plus building upkeep costs) as used in the accounting system of this factory are $0.50 per square foot of floor area per year. A hand shaper will use 50 square feet of floor space, and an automatic will use 75 square feet. Any space saved in this part of the factory can be used to advantage for other purposes. Despite the practice in this factory of allocating indirect manufacturing expense (burden) in proportion to direct labor costs, it is apparent that no other indirect expenses will be altered by the choice between the two types of shaper.

From these estimates, the annual cost comparison is as follows:

	2 Hand Shapers	1 Automatic Shaper
Capital recovery:		
Depreciation (5 year life)	$1,020	$1,540
Average interest (i=8 percent)	245	370
Taxes and insurance	127	192
Direct labor	6,033	2,674
Maintenance and repairs	120	40
Power	216	393
Supplies and lubricants	10	5
Space expense	50	38
Total Annual Cost	$7,821	$5,252

It will be noted that this study was not based on unit costs with full-time production with the machines, but rather on estimated total annual costs based on the expected annual output. The use of expected output rather than potential capacity is essential in studies of this type, if investments are to be justified on a realistic basis.

An economy study comparing unit costs at full-time operation of 2,000 hours per year would have favored the automatic shaper, just as the economy study did based on the expected annual output of 20,000 chairs. However, if the expected annual output had been 2,000 chairs instead of 20,000 and the comparison had been between *one* hand shaper and one automatic shaper, the use of unit costs based on full-time operation would have given the wrong conclusion.

When two alternative machines of different capacity are being compared for a service for which the one of the smaller capacity is adequate, the excess capacity provided by the larger-capacity machine should be recognized as an irreducible in its favor. But comparisons of "unit costs" based on the assumption of full-time operation may be very misleading in circumstances where full-time operation is not likely to occur.[2]

New for Old

There is probably more replacing of new machines and methods for old equipment and methods. Then there is the question of mechanizing and conveyorizing in order to improve the methods.

Many contemplated machining replacements have a very large labor-saving factor. In these cases, it is possible to disregard small items such as power and maintenance costs. One of the best examples of this is in the application of veneer edge bands. It has been common practice in the furniture industry to apply these bands in batch type clamps using resistance heaters. Glue is applied by hand to each individual panel, and the panels are then put into a mechanical clamp which applies heat and pressure for a specific period, usually 1 to 2 minutes.

Not long ago, a European manufacturer introduced into this country a continuous feed veneer bander. In this machine the glue and bands were applied automatically, the panels passed through a heat and pressure zone, and then the over-sized veneer was trimmed top and bottom. The operators had only to feed the panels, and the offbearer had to break the veneer overhang on the ends. A third man kept glue made up, veneers in hoppers, and stock to and from the machine.

For example, the economics of this type machine replacement can be considered as a new method and machine compared with old machines. In the first analysis a large production plant is used which would require 1,600 panels 18 inches wide by 36 inches long per day. The problem is to apply 1/28-inch veneer to both sides in the 36-inch direction. Theoretically, a time cycle of 1 minute in the batch type clamps gets 450 panels per day per clamp. Four clamps would be required to obtain the necessary 1,600 panels per day. In the continuous edge bander it has been empirically determined in other furniture plants that it will produce 200 panels per hour with some additional capacity.

For each batch-type clamp, two men are required to apply glue and bands to both edges. This makes a total of eight men. Only three men on the continuous machine are required for the indicated production. It is clear that a great savings is indicated, but the analysis can be continued further.

Direct labor for batch clamps, 8 men @ $3,500/year	$28,000	
Direct labor for continuous bander, 3 men @ $3,500/year	10,500	
Net labor savings		$17,500
Capital investment, installed		10,000
Net saving per first year		$ 7,500

The actual capital investment would be $2,000 per year if the machine were amortized in 5 years.

In this case it would not be necessary to consider some of the lesser items on the economy study list to ascertain that this investment should have a high priority. However, not many situations arise that are as obvious as this one. If so, it would be easy for management to make the decision to buy or not to buy.

In the previous example it was considered that the plant required all of the capacity of the continuous veneer banding machine. There is another situation that would apply to a great majority of furniture manufacturers. Suppose there is a panel requirement of 300 per day of the same type as described. It is assumed that the extra time of the men on both operations can be utilized elsewhere. The same data is used for other costs as listed in the shaper example.

	1 Automatic Edge Bander	1 Batch Type Clamp
Capital recovery:		
Depreciation (5 year life)	$2,000	$ 400
Average interest (i=8 percent)	480	96
Taxes and insurance	250	50
Direct labor	2,550	5,100
Maintenance and repairs	60	25
Power	87	75
Supplies and lubricants	100	25
Space expense	75	25
	$5,602	$5,796

Here is a case where the automatic machine probably would not be advisable. If production requirements increased, however, the annual costs of operating the automatic machine would increase very little, while the annual costs for operating the batch clamp would increase proportionately with the number of clamps in use.

Mechanization

The best example of mechanization, which is one of improved methods, is the rough mill. In this example, there is a plant that processes 12,000 board feet of rough lumber per day. In the existing setup there are no conveyors, and all stock is moved from machine to machine by shop trucks and hand fed to all machine operators. In the planned setup, conveyors will be used to feed all machines where practical.

Existing Method— Manpower Requirements	
Lumber handlers	2
Cutoff saw operators	2
Ripsaw operators	4
Ripsaw tailboys	4
Planer operators	2
Facer operators	2
Edge jointer operators	3
Salvage operator	1
Total men	20
Proposed Method— Manpower Requirements	
Lumber handlers	1
Cutoff saw operators	2
Ripsaw operators	3
Ripsaw tailboys	3
Edge jointer feeder	1
General man (prevents jams)	1
Salvage operator	1
Total men	12

[2] Grant, E. L. Principles of Engineering Economy. Third edition. The Ronald Press Company, New York. p. 316 ff.

Note: The use of conveyors increases the capacity so that 3 ripsaws can produce the same volume as 4 previously.

Existing methods labor cost per 1,000 board feet	$23.33
Proposed methods labor cost per 1,000 board feet	14.00
Net Savings per 1,000 board feet	$ 9.33
Annual Savings Direct Labor	$28,000.00

Investment in Conveyors	$50,000	
Annual Depreciation		$10,000
Avg. Interest (i=8 percent)		2,400
Maintenance and Repairs		500
Power		150
Space		100
Total other costs		$13,150
Annual Labor Savings		$28,000
Less Other Annual Costs		13,150
Total Net Savings Per Year		$14,850

Here is a case where large savings are apparent, however, the capital investment is considerably larger than the previous example. The question as to whether or not to mechanize the rough mill, even with the large possible indicated savings, must be resolved in the light of capital available, necessity for other smaller capital improvements which might be of equal advantage, as well as other local situations that exist and differ from plant to plant. In this case, the idea of having economic studies of all planned replacements and improvements is well illustrated. If such studies exist, it would then be possible to weigh one against the other.

In the particular problem above, the personnel problem would exist until all became familiar with the new method of operation. Also a disruption of production would occur. All of these factors would have to be taken into account when making the decision to mechanize, whether in the rough mill or in other departments.

Other Factors

Physical and mental limitations of personnel should be mentioned, they are factors which must be determined when any machine replacement is considered, especially the type where new and special type machines are concerned. Personnel must learn something new, while at the same time be required to get out production and various other factors. Many times men prefer not to operate new machines because of some theory they may have about them. This can be overcome by proper instruction and training on the part of supervisors and installation personnel. Many workmen take pride in the fact that they have a new machine to operate and will do a much better job than they would have on an older machine. Likewise, they will tend to take care of it and provide the proper maintenance to keep it in good working condition. It would be difficult to list these items in a dollar and cents figure, but they are extremely important.

Very few types of machine replacement can be accomplished without some disruption of production. This disruption however can be kept to a minimum with proper planning and instruction on the part of all involved. In most cases, new machines where there are only one or two involved, can be installed over week-ends or holidays, and no production time would be lost in getting the machine in its proper location. When a group of machines is to be installed, it is obvious that some lost time will be incurred. For this reason the scheduling of work should be done so that the off time on this particular operation would be a minimum while the machinery is installed and given trial runs.

Included in this planning for machine replacement is an item which is very important. Each plant should have an overall plan for their plant growth and production facilities. If a plan of this type is available and new machines are purchased, they can be placed properly in order of manufacturing sequence without moving a great deal of other machinery in order to get them in the right place. Plans of this kind can be made on a 3-year, 5-year, or whatever other basis management might determine. This would help to eliminate some of the previous mentioned problems such as disruption of production. When this overall plan is made, it would be necessary to make up a priority list for machinery that is to be purchased or added. When this priority is established, some of the questions concerning machine replacement are answered. The most important item should be purchased first and so on down the line.

The plan which is made should not be one that could not be changed easily. Each year brings out new machinery and new jobs which must be done with woodworking machinery. Therefore, it should be kept in mind when making future plans that there should be sufficient flexibility to take care of any obsolescence during the planned replacement period.

Consultants

There are many sources of help available in determining when machine replacement should be done and how it should be done. All of these sources can act as a guide to the one who makes the decision to purchase. The outside consultant can be of great help in determining when machines should be replaced. He is especially helpful in making the overall plan and layout that would best fit the particular operation. He may draw upon his experiences in other plants in all parts of the United States, and some consultant are well familiar with plant operation all over the world. He is offering advice as to the best type of machine to do the job for the particular plant.

Most machinery suppliers and manufacturers have engineers who can make economic analysis of the machines with which they are concerned. These engineers are very reliable and are useful in their business. They are well trained and can make a detailed study of the economics concerned with a machine of the type they are selling. These economic studies certainly should not be overlooked even when a plant has its own engineering department. It would prove a good check against the analysis made by a plant's own personnel. It is possible that some machinery manufacturers' engineers tend to be a little biased due to the pressure of selling, however, most of them are reliable, and the figures obtained should give a true picture of the costs of the machine.

Another very good source is a company's own plant personnel. Supervisors usually have good opinions on new machinery, especially so if they have seen a new machine in operation in another plant. Most supervisors are able to visualize a machine in operation and can use a rule of thumb in determining how it would help them. At times, however, these men are under pressure and feel compelled to ask for the cheapest machine, even though a little more expensive machine might pay off more in dollars saved. It is in these areas that plant personnel do not always see the full picture.

Conclusion

The most important aspect of the economics of machine replacement is the determination of what must be done with the machine, what the machine that is being considered will do, and how long it will take for the machine to pay for itself or return the investment. The dollars and cents initial cost of a machine is not the most important factor, even though it is a major item in most cases. After the foregoing points are taken into consideration and indications are that the machine will do the job required and return the investment on a sound basis, then the machine should be purchased and put into production.

Factors Affecting Sawmill Output[1]

Every sawmiller realizes that a mill cannot process logs of a given size only. The author illuminates, however, several things that sawmill management can do to maximize profit for a mill. With this information, the mill operator is in a position to make decisions and establish policies consistent with current economic conditions and physical limitations of men and equipment.

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THE PRIMARY FUNCTION OF SAWMILL MANAGEMENT is decision making. Development of policies consistent with the goals of the firm requires choosing the most reasonable of various alternatives. Today economic pressures dictate that such decisions be precise and accurate.

One area of management-concern relates to answering such questions as:

What is the break-even point in sawing logs of various sizes? If logs below a given size cannot be sawn profitably with present equipment and objectives, perhaps an investment in a separate mill to handle small logs is warranted—but this requires a definition of "small" logs.

What is the effect of winter temperatures on output? Is the effect of temperature sufficient to warrant better housing for men, logs, and equipment?

What is the significance of lost time? Is 20 minutes of lost time per shift significant? Is 5 minutes? Is 40 minutes?

Faced with such questions and numerous others, management must give renewed attention to understanding each of the factors associated with changes in mill output. First these variables must be identified; and second their influence must be measured. Only then is the evidence adequate to make appropriate decisions.

As a first step in approaching the problem of sawmill efficiency, we will limit our attention to one phase of the operation: factors affecting sawmill output, log scale at the headsaw. Reason leads us to believe that for a given mill, influential variables will be lost time, season, log size (diameter and length), proportion of defect, species, lumber demand (for specified items and amounts), and efficiency of men and equipment.

The idea that log size, for example, is related to output is not new to sawmillers. Too often, however, studies have looked at the relationship betweeen log size and output without recognizing the influence of other variables. Such an approach can be misleading.

This is not a study based on a small sample. It is based on records from more than 761,000 logs processed at one mill over an 11-year period. These logs represent 110 million board feet, log scale. Each log was scaled as it entered the log deck, and the scale and the amount of defect were recorded. Times during which the normal sawing operation was interrupted were also recorded.

The mill studied is a double-cutting band mill, steam operated, with a setter riding the carriage. Usual production is about 50 thousand board feet, log scale, per 8-hour shift. The source of the log supply processed during this period was mainly Ferry County and western Stevens County as shown in Figure 1.

Log Size

Distribution of Log Size: The distribution of average log size is shown in Table 1. Seldom did the mill process logs which averaged larger than 22 inches at the small end or less than 10 inches during any one working day, except in the case of cedar. The average 16-foot pine *(Pinus ponderosa)* log was 16 inches, fir *(Pseudotsuga taxifolia)* and larch *(Larix occidentallis)* 14.5 inches, spruce *(Picea engelmanni)* 14 inches, and cedar *(Thuja plicata)* 11 inches.

Table 2 shows the number of logs and volume processed for each species during the period studied.

Changes in Log Size Over Time: The size of logs processed has been changing over time. Each year the average log has become smaller. During the period studied (1949 to 1959), pine logs dropped from a daily average of slightly over 17 inches (small end) to about 15 inches. During the same period, fir (Douglas-fir and larch) logs decreased from 16 inches to 13.5 inches. If the trend continues during the next 10 years, by 1970 pine logs will average 14 inches and fir logs 12 inches. (See Figure 2) Continuation of the trend will depend on both availability of

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Fig. 1.—Source of log supply processed in mill studied. Most of the logs were harvested in Ferry County and western Stevens County.

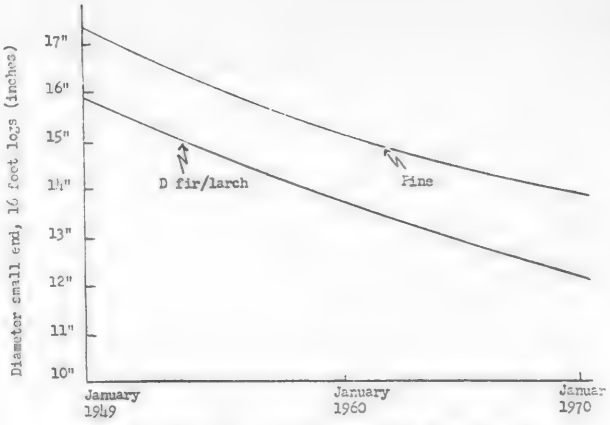


Fig. 2.—Changes in average log size, 1949–1959. (Estimated for 1959–1970.)

logs of various sizes and management policy which determines the size of log to be processed. Such policy might be based on limitations of equipment as well as profitability of sawing logs of various sizes.

Proportion of Defect

Usual Proportion of Defect: Table 3 shows the average daily proportion of defect found in logs processed. (As used here, defect is the proportion of each log not usable as lumber.) Pine, fir, and spruce logs averaged about 1 percent defect, while cedar averaged about 2 percent. Pine, fir, and spruce defect may average as high as 6 percent on some days—while cedar can be expected to reach as high as 15 percent.

Relation of Defect and Log Size: Is it to be expected that the percentage of defect will vary with the log size? Do smaller logs have a higher proportion of cull volume than larger logs or vice versa? Use of regression analysis to test the degree of correlation between cull volume and log size showed "no correlation" for all species tested. In other words, the proportion of cull would not necessarily be expected to be greater in either large logs or small logs, within the limits of the log sizes tested (in this case, 12 to 22 inches for the species included in the study). Probably, if more larger logs would have been included it would have been shown that the larger old growth logs, especially if from overmature trees, do have a higher percentage of defect. Defect is usually related to both age and species.

Lost Time

Seasonality of Lost Time: In general, lost time per shift was about the same for February through October; however, lost time increased during November through January. The average for February through October was 23 minutes of lost time per 8-hour shift; for November through January, 32 minutes. The difference between 23 and 32 is statistically significant. Thus, a valid statement is: lost time per shift is less during the months of February through October than for the months of November, December, and January.

Certainly a valid question may be raised here: 9 minutes (the difference between 23 and 32) may be statistically significant, but is it significant to an individual operator?

One answer may be given for the mill studied in terms of lost income. This mill's average output per effective 8-hour shift for the entire period studied was 48 thousand board feet. Their output per effective minute was 100 board feet.

During the months of November, December, and January, they can expect to lose 3,200 board feet per 8-hour shift due to lost time. In terms of lost income, this output would have been worth $233 based on the 1959 Western Pine Association weighted average price of the value cut from

Lost output during February through October would be 2,300 board feet, valued at $160. Thus, it costs $63 a shift more during November, December, and January in terms of lost income. The average number of shifts worked during November, December, and January for the period studied was $54; thus the loss due to season is 54 times $63, or $3,400 a year at this mill.

As any sawmill manager knows, lost income is not the only consideration. Cost per unit of output is also greater when lost time is incurred. In terms of dollars and cents, every minute of lost time is costly.

The higher lost time for November through January suggests that lower temperature may be related to increased lost time. Investigation showed that above 32° F., temperature did not effect lost time greatly; but below 32° F., lost time increased at a rate of 6 minutes per 8-hour shift for every 10° F. drop in temperature (see Figure 3).

Perhaps this suggests that investment is warranted to minimize the effects of temperature on logs, men, and equipment. Such measures might be in the form of housing to protect men and equipment from the cold; for example, a warm cage for the sawyer may be worthwhile; or a hot pond; or better equipment for sawing frozen logs, as a debarker to remove frozen mud and rocks.

Relation of Lost Time and Log Size: Lost time is related to season. Is it also related to log size? Is down time greatest when sawing big logs? Apparently not. The relationship between the proportion of lost time and the number of logs per thousand board feet was proved to be "not correlated."

Factors Affecting Sawmill Output

Let us return now to our hypotheses: sawmill output, log scale, at a given type of mill, depends on log size, proportion of defect, lost time, season, species, lumber demand, and operating efficiency.

A preliminary look at log size, proportion of defect, lost time, and season seems to confirm our selection of those variables. In addition, species would seem to be of some importance, since the items sawn will vary from species to species. It should take more time to saw boards than dimension if they are sawn on the headrig. In the same manner, lumber demand should influence the sawyer's decision as to which items to saw, whenever he has a choice; and some items take longer to saw than others.

Of course, it is also to be expected that the sawyer will become more efficient as he gains experience, and efficiency should be related to the volume sawn.

One other factor—log length—may have some effect. At the mill observed, over two-thirds of the logs processed were 16 feet long. (The remaining one-third was between 12 and 20 feet.) We will assume then, that log length was 16 feet for all logs. Such an assumption is not precisely valid but should be adequate for our purpose.

Selection of Variables: The variables selected were represented as follows:

X_1, output per effective hour: actual working time not including lost time, in board feet, Scribner Decimal C log scale.

X_2, log size: daily average number of logs per thousand board feet, Scribner Decimal C log scale.

X_3, season: average monthly temperature.

X_4, operating efficiency: efficiency is a function of both man power and equipment and results from changes which occur at various times and in various ways. For our purpose, we will let time, expressed in months, be the variable representing changes due to efficiency. The influence of technological innovations is also measured by this variable.

X_5, species: in the mill studied, about one half of the output was pine. Furthermore, during the period studied, pine decreased in importance from 75 per cent of the output in 1949 to only 37 per cent in 1959. Since pine would be expected to require more sawing time than fir, the other major species sawn, the average daily percentage of pine was chosen to represent the influence of species.

Table 1.—DISTRIBUTION OF LOGS SAWED, SHOWING THE PERCENTAGE OF LOGS ON DAYS IN WHICH THE AVERAGE DAILY LOG SIZE FELL WITHIN SPECIFIED LIMITS

Average daily log size (inches)	Percent of logs, each size			
	Pine %	Larch/ D fir %	Spruce %	Cedar %
22+	00.2	00.1	00.0	00.0
18–21.9	21.0	00.6	00.5	15.8
14–17.9	72.2	53.5	53.6	26.8
10–13.9	06.3	45.6	44.7	44.9
Under 10	00.3	00.2	01.2	12.5
	100.0	100.0	100.0	100.0

X_6, lumber demand: when an order is received, and a shipment date selected, the manager will see if the material is in the inventory, or expected to be through the normal development of items from the material being sawn. If it is not, he may ask that a specified size and species of logs be moved to the log deck for sawing, and he will advise the sawyer to look for the items desired. Thus, it was felt, new orders should be a good indicator of lumber demand. For our purpose, new orders in the western pine region was used.

X_7, proportion of defect: daily average percentage of defect, log scale, in logs processed.

We have now identified what we consider to be the influential variables affecting mill output. The next step is to measure the importance of each by showing the extent of each variable's influence. The method used for analysis was multiple regression. The final regression equations will be found in Appendix A. Multiple regression analysis permits us to measure the influence of each variable separately while holding the influence of all other variables constant. Such analysis gives us a picture of the net influence of any one variable.

The following variables were found to have no measurable influence on output per effective hour: lumber demand, proportion of cull, and species. Is such a conclusion reasonable?

Table 2.—NUMBER OF LOGS AND VOLUME PROCESSED FOR EACH SPECIES

Species	No. logs	Vol. (MM bd. ft.)
Pine	354,033	61.9
D Fir/larch	357,299	42.0
Spruce	45,615	5.4
Cedar	4,264	0.5
Total	761,211	109.8

Lumber Demand: The conclusion that lumber demand does not influence output per effective hour may perhaps be rationalized best as follows. Once a mill is committed to operation, the output may logically be a function of non-economic variables such as log size, season, and operating efficiency; but lumber demand as an economic indicator, certainly influences the decision to operate. Thus, we might say that lumber demand will influence the number of working hours a mill operates, but other variables will influence the output per working hour. To the extent that lumber demand influences management and sawyer's decisions, it would be a factor affecting output. This influence, however, was not great at the mill studied.

Proportion of Defect: It would seem that higher proportions of defect in each log sawn would cut down output per hour. Probably this variable was not significant because the percentage of defect experienced was so small, i.e., as noted previously, the average proportion of defect in pine, fir, and spruce averaged only 1 percent of the total volume sawn.

Species: The proportions of pine sawn during a shift did have an influence on quantity sawn, but not great enough to be statistically significant. The extra time necessary in sawing

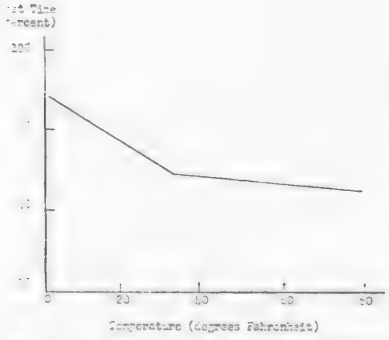


Fig. 3.—Relationship between percentage of lost time and average monthly temperature.

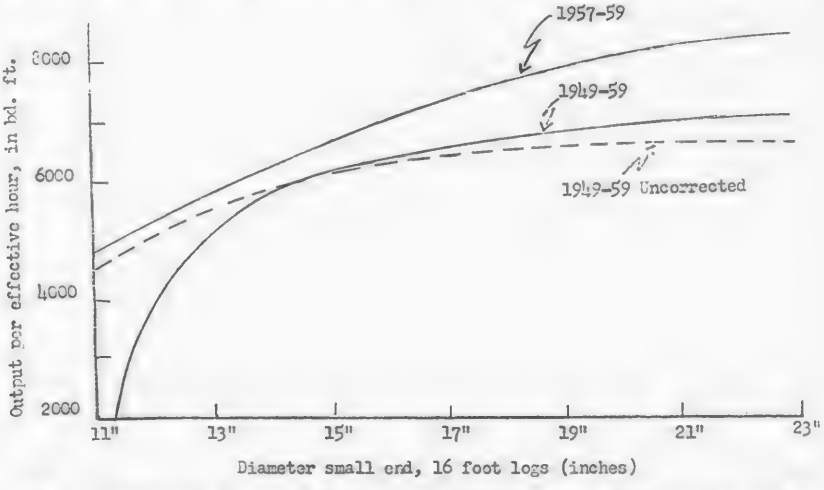


Fig. 4.—Relationship between mill output per effective hour, log scale, and log size. The solid lines represent the net relationship of output and log size with the effect of season, efficiency, and lost time held constant. The dotted line represents the relationship of output and log size without the effect of season and efficiency considered, for the period 1949–1959.

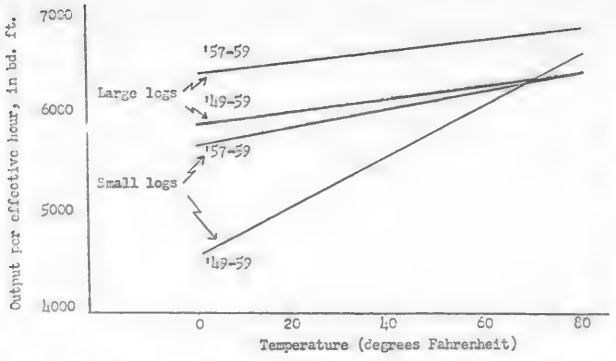


Fig. 5.—Relationship between sawmill output per effective hour, log scale, and average monthly temperature, for large logs (over 15 inches) and small logs (under 15 inches, small end). The effect of log size, efficiency, and lost time is held constant.

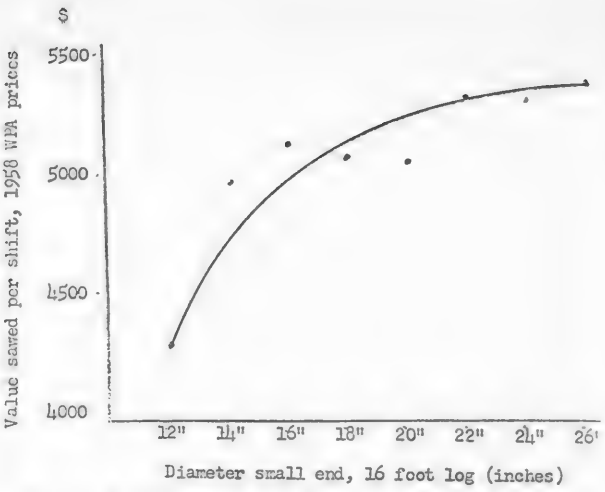


Fig. 6.—Relationship between value sawed per shift and log size, number 3 Douglas-fir sawlogs.

pine was not great. Pine logs are expected over a period of time to yield about 60 percent common boards and selects, while fir logs produce nearly 70 percent of thicker dimension. Cutting boards requires more carriage trips and turning and, hence, more time than cutting dimension.

The variables which did have important influence on the level of output were log size and season.

Log Size: The relationship between mill output per effective hour and log size is shown in Figure 4. This shows the net relationship, with the effect of season, operating efficiency, and lost time held constant. Looking at the lower solid line, showing the entire period of 1949 to 1959, it can be seen that this mill could saw only about 3,000 board feet, log scale, per effective hour, when sawing logs that averaged 12 inches during a working day. Increasing the log size to 14 inches, increased output to nearly 6,000 board feet per effective hour; and increasing the log size to 22 inches increased output even further, to nearly 7,000 board feet per effective hour. The influence of log size was greatest when sawing logs that averaged under 14 inches during a working day; over 14 inches, log size is still important, but not as significant.

The upper line in Figure 3 shows the relationship between output and log size during the last three years, 1957 to 1959. During this period, the mill was able to cut about 5,300 board feet per effective shift hour when handling logs averaging 12 inches; and output increased to 8,100 board feet per effective hour when handling logs averaging 22 inches. It appears that mill efficiency was improved during the last 3 years, thus minimizing much of the detrimental effect of sawing small logs. Nevertheless, the basic impact of log size remained: the smaller the logs sawn, the less the output per effective shift hour. It was noted earlier that one could be misled by observing the relationship between output and log size without taking into consideration the effect of other influential variables (in this case, season and operating efficiency). Had the effect of these variables not been considered, we would have concluded that this mill could produce 5,200 board feet per effective hour cutting 12-inch logs, and 6,500 board feet cutting 22-inch logs (dotted line, Figure 4). Thus, the true effect of log size would not have been shown.

Season: As shown earlier, average monthly temperature is a fairly good index of seasonality. The net relationsip between output per effective shift hour and temperature is shown in Figure 5. It can be seen that the effect of temperature is not great for large logs (over 15 inches). Nevertheless, lower temperatures always mean lower production for any given log size. For any given level of efficiency and log size, output during the winter months would be expected to be less than during the summer months. Furthermore, winter temperatures have the effect of magnifying inefficiencies associated with sawing small logs. The output is always less when sawing small logs, but the difference is even greater when sawing small logs in the wintertime.

Combined Effects of Log Size, Season, and Lost Time: It is interesting to observe how marked the combined influence of the most important variables when acting together. With warm temperatures, large logs, and no lost time, during the period from 1957 to 1959, output in this mill would have gone as high as 67 thousand board feet per shift. But with small logs, low temperatures, and 24 minutes of lost time per shift (average for 1957 to 1959) mill output dropped to as low as 38 thousand board feet per shift (see Appendix B).

The top capacity of this mill could thus be considered 67 thousand board feet, log scale, per shift. The actual average production for 1957 to 1959 was 50 thousand board feet, or 75 percent of capacity, due to the influence of season, log size, and lost time.

Summary and Application

Changing Log Size: Tangible evidence that logs being processed in the region are getting smaller should encourage a close look at the causes of this phenomenon. If it is a trend that will continue, it becomes urgent that each mill operator determine the minimum size log that can be sawn profitably at various price levels. A close look at the limitations of present equipment is also suggested. This may not be the time to invest in equipment that will handle bigger logs—such investments may turn into over-investment if the trend in log size continues. Mill operators must consider carefully the size of the logs they can handle profitably—and eliminate logs outside those size classes to the extent they can. Perhaps the smaller logs can be resold to, or traded with, pulp manufacturers; and the larger logs to veneer

Table 3.—PERCENTAGE OF DEFECT, BY SPECIES, IN LOGS SAWED

Species	Average percentage defect	Standard Deviation	68% limits	95% limits
Pine	1.322%	2.025%	0- 3.347%	0- 5.372%
D fir larch	0.863	2.049	0- 2.912	0- 4.961
Spruce	0.559	3.014	0- 3.573	0 -6.587
Cedar	1.789	6.706	0- 8.495	0-15.201

plants. Or perhaps a separate mill to handle excessively large or excessively small logs should be investigated. A number of mills have already found such an investment to be feasible.

Machinery manufacturers too, would do well to look carefully at the trend to smaller logs, as would loggers, lumber sales people, utilization researchers, and forest managers. Maybe the trend should be arrested.

The chief point here is not the validity of any estimate of what the future holds—but the implications if the trend is correct.

Lost Time: Lost time is that time during which the normal sawing operation is interrupted. It has been shown that this lost time is greatest during periods of low temperatures, particularly during the months of November, December and January. The high cost of lost time associated with low temperatures suggests a careful look at the cause of lost time since, for this mill at least, it is probably great enough to warrant investment to protect men, equipment, and logs from the cold. This high cost results from less output per dollar of fixed cost, and also from lost production. It was further noted that lost time was unrelated to size of logs being processed for this particular mill.

Percentage of Defect: It was found that although pine, fir, larch, and spruce usually average about 1 percent defect in logs between 12 and 22 inches in diameter, defect sometimes ranged as high as 6 percent. Cedar averaged about 2 percent, sometimes ranging up to 15 percent. For logs between 12 and 22 inches, percentage of defect was no greater in larger logs than in smaller logs.

Factors Affecting Output: Demand for lumber, proportion of defect, and species being sawn did not affect mill output, log scale, per effective shift hour significantly. However, log size and season did have a measurable effect on output.

The negative influence of sawing small logs was greatest for logs averaging under 14 inches during a working day.

Winter temperatures not only cut down production but also magnified the inefficiency of sawing small logs.

If conditions of log size, temperature, and lost time were controlled in the mill studied, production would have been 67 thousand board feet, log scale, per 8-hour shift. But sawing small logs in winter temperatures could cut production to 38 thousand board feet, or only 57 percent of capacity (see Appendix B).

Adjustment for Over-run and Grade Recovery: One additional step is now needed to make the information derived most useful—adjusting mill output data, log scale, for overrun and grade recovery.

Since lumber tally data are not available for the present study, it will be necessary to rely on an unpublished Forest Service study of four mills in eastern Washington and Oregon to show how the information can be applied.

Using the regression equations for 1957 to 1959 to predict mill output, log scale, (see Appendix A) we can compute the output to be expected from sawing logs of various sizes. This is shown in Table 4, column 3. Then using the Forest Service data showing overrun and value per thousand board feet of lumber cut from each size of log, we can derive a total value sawn per shift based on the Western Pine prices during 1958 (Table 4, column 8).

Total value to be expected from sawing logs averaging from 12 to 26 inches during an 8-hour shift is plotted in Figure 6. From this graph it can be seen that if the overrun and grade recovery data are accurate for the mill studied, value sawn per shift decreases rapidly as log size decreases.

If production costs and value derived are both computed for the same time period in terms of cost per 8-hour shift for each size log, the break-even point in log size can be located on Figure 6. For example, 14 inch number 3 Douglas-fir logs could be sawn profitably as long as production costs for 14-inch logs are not greater than $4,750 per shift.

Most Profitable Log Size: Sometimes, it is difficult to determine total production costs. A technique not hampered by lack of knowledge of production costs is marginal analysis. All that is necessary in addition to the facts shown in Table 4 is variable costs per 8-hour shift for each log size. This will permit computation of the most profitable log size.

Table 4.—METHOD OF ADJUSTING OUTPUT PER EFFECTIVE HOUR DERIVED FROM PRESENT STUDY FOR OVERRUN AND GRADE RECOVERY

(1) Diam. in.	(2) No. of Logs/M	(3) Output Per eff. hr. Log scale Bd. ft.	(4) Over-run Pct.	(5) Output/hr. Lumber Tally Bd. ft.	(6) Value/M 1958 $	(7) Value/hr. $	(8) Value per shift $
12	12.50	5288	39	7350	77.60	570.36	4335
14	9.09	6267	44	9024	73.10	659.65	5013
16	6.25	7018	37	9615	70.80	680.74	5174
18	4.76	7517	28	9622	69.80	671.62	5104
20	3.57	7968	20	9562	69.80	667.43	5072
22	3.03	8173	22	9971	70.00	697.97	5305
24	2.50	8373	19	9964	70.50	702.46	5339
26	2.00	8563	17	10019	71.00	711.34	5406

Appendix A.—REGRESSION EQUATIONS

Time Period	Sample size (months)	Least squares equations[a]	R^2
		Large logs, 8.11 or less logs/M	
1957–59	20	$X_1 = 8502 - 378.71 X_2 + 6.15 X_3 + 4.57 X_4$ (99.66) (4.95) (8.27)	.53
1949–59	95	$X_1 = 6468 - 183.40 X_2 + 6.72 X_3 + 10.37 X_4$ (47.98) (2.69) (1.18)	.46
		Small logs, 8.12 or more logs/M	
1957–59	15	$X_1 = 7580 - 287.20 X_2 + 9.15 X_3 + 7.59 X_4$ (70.4) (2.86) (4.95)	.68
1949–59	22	$X_1 = 13273 - 1019.90 X_2 + 25.85 X_3 + 8.83 X_4$ (221.2) (11.35) (8.51)	.65
		All logs	
1949-49	2328 days	$X_1 = 6347 + 106.52 X_2 - 15.70 X_2^2$ (58.5) (3.84)	$r^2 = .09$

[a] X_1 = Output per effective hour.
X_2 = Daily average number of logs/M.
X_3 = Average monthly temperature.
X_4 = Time, expressed in months. Each month was assigned a number, with January, 1949 being month 1; and December, 1959 being month 132.
The standard error of the regression coefficients are given in parenthesis under each coefficient.

Appendix B.—COMPUTATIONS OF OUTPUT UNDER SPECIFIED CONDITIONS

1. During 1957–59, with average monthly temperature of 70 degrees, logs averaging 3 logs/M (22" small end of 16 foot log), and no lost time, mill output would be:
$8502 - 378.71 X_2 + 6.15 X_3 + 4.57 X_4$ = Mill output per effective hr.[a]
$8502 - (378.71)(3) + (6.15)(70) + (4.57)(114)$[b] = 8317 bd. ft. per effective hr.
Or, (8317 bd. ft. per effective hr.) X (8 hours) = 67 M per effective shift

2. During 1957–59, with average monthly temperature of 10 degrees, logs averaging 12.5 logs/M (12" small end of 16 foot log), and 24 minutes of lost time per shift (actual average during 1957–59), mill output would be:
$7580 - 287.2 X_2 + 9.15 X_3 + 7.59 X_4$ = Output per effective hour
$7580 - (287.2)(12.5) + (9.15)(10) + (7.59)(114) = 4947$ bd. ft. per effective hr.

Due to lost time, the effective shift is only 7.6 hours instead of 8, thus (4947 bd. ft. per effective hr.) X (7.6 hours) = 38 M per effective shift.

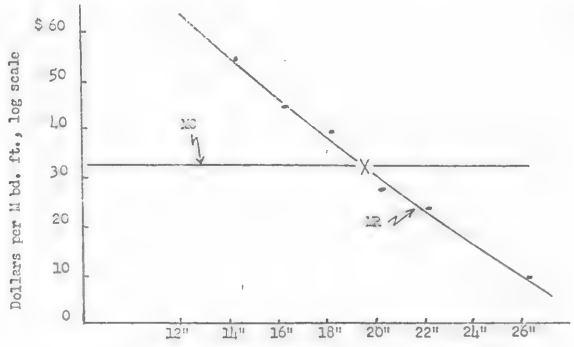
3. The combined influence of log size, temperature, and lost time thus have the effect of cutting output to 38/67 or 57% of capacity.

[a] X_2 = Daily average number of logs per M.
X_3 = Average monthly temperature.
[b] X_4 = Time, expressed in months. Each month was assigned a number, with January being month 1; and December, 1959 being month 132. In this example, month 114 was used since that represents June, 1958, the mid-point of 1957–59.

Appendix C.—MOST PROFITABLE LOG SIZE, SAWING GRADE 3 DOUGLAS-FIR LOGS

Diam. In.	Input M ft. log scale	Change in Inputs M bd. ft.	Total Revenue $	Change in Revenue $	Marginal Revenue $/M	Variable Cost $	Change in Variable Cost $	Marginal Cost $/M
12	42.3		4285			1396		33
14	50.1	7.8	4715	430	55.13	1653	257	33
16	56.1	6.0	4985	270	45.00	1851	198	33
18	60.1	4.0	5145	160	40.00	1983	132	33
20	63.7	3.6	5245	100	27.78	2102	119	33
22	65.4	1.7	5285	40	23.53	2158	56	33
24	67.0	1.6	5330	45	28.13	2211	53	33
26	68.5	1.5	5345	15	10.00	2260	49	33

Computation of marginal revenue and marginal cost per unit of input per shift. Input is the log volume that can be sawn during a shift. Revenue is the value of the lumber sawn from grade 3 Douglas fir sawlogs during a shift. Marginal revenue (MR) equals change in revenue ÷ change in inputs. Marginal cost (MC) equals change in variable cost ÷ change in inputs.



Most profitable log size. About 19 inches average daily log size will maximize profit or minimize loss when sawing grade 3 Douglas-fir sawlogs.

Appendix D.—MAXIMUM LOG PRICE POSSIBLE UNDER ASSUMED LEVEL OF FIXED COSTS FOR GRADE 3 DOUGLAS-FIR SAWLOGS

Diam. In.	Total Revenue $	Total variable cost $	TR-TVC $	Assumed fixed cost $	Net Revenue $	Input log scale M	Profit or loss per M $	Maximum log price pr M $
12	4285	1396	2889	3062	−173	42.3	−4.09	28.91
14	4715	1653	3062	3062	00	50.1	0.00	33.00
16	4985	1851	3134	3062	72	56.1	+1.28	34.28
18	5145	1983	3162	3062	100	60.1	+1.66	34.66
20	5245	2102	3143	3062	81	63.7	+1.27	34.27
22	5285	2158	3127	3062	65	65.4	+0.99	33.99
24	5330	2211	3119	3062	57	67.0	+0.85	33.85
26	5345	2260	3085	3062	23	68.5	+0.34	33.34

Total revenue and total variable costs are for an 8 hour shift. (See Appendix C).
Net revenue ÷ Input, log scale = Profit or loss per M.
$33.00 ± Profit or loss = Maximum log price.

In this case, variable costs are those costs that change as levels of production change during an 8-hour shift. And, since by far the most important variable cost is the cost of logs, the most profitable log size can be determined knowing only two things: the relationship between log size and value cut per shift (Table 4); and the cost of logs.

The computations, using number 3 Douglas-fir logs for example, appear in Appendix C. The log cost used was $33. The point where marginal cost equals marginal revenue is the level of output that maximizes profit. Net revenue will always be less on either side of the equality of marginal cost and marginal revenue.

In this example, number 3 Douglas-fir logs which average about 19 inches during an 8-hour shift would return the most profit. Logs less than 19 inches produce less output per dollar of cost because of the inefficiencies of sawing smaller logs. On the other hand, logs over 19 inches do not produce sufficiently greater value (because of the interaction of overrun, grade recovery, and sawing economy) to warrant the additional cost due to increased volume sawn.

It should be noted that the most profitable size may be different for grades and species of logs other than the one use in this example. Furthermore, this technique has a limitation. It will show either the point of maximum profit or minimum loss—it does not enable the operator to determine which. If it is profitable to operate, it is profitable to operate at the point where marginal cost equals marginal revenue. Determination of the amount of profit or loss depends on knowledge of fixed costs in addition to variable costs.

Perhaps dissemination of this type of information could have another implication. If larger logs are more desirable, any resulting increased demand is likely to be reflected in higher prices for such logs. Thus the question might be asked: how much more can the sawmiller afford to pay for larger logs than for smaller ones?

Using the same costs and revenues assumed for number 3 Douglas-fir logs; and assuming the level of fixed costs to be just high enough to permit the mill to break-even sawing 14 inch logs, the maximum log price for each size can be computed. Computations appear in Appendix D. If the mill breaks even paying $33 for 14-inch number 3 Douglas-fir logs, the maximum price possible for 12-inch logs would be $28.91; or $34.28 for 16 inch logs; $34.66 for 18 inch logs, etc.

The earlier conclusion that net revenue is maximized between 18 and 20 inch logs is also confirmed by this illustration.

Conclusion

Every sawmiller realizes that a mill cannot process logs of a given size only. But sawmill management can do two things: adapt log buying policies and timber cutting practices wherever possible; and/or adapt the mill to the size of logs available to the extent it is feasible. This type of analysis shows the size of log that will maximize profit for a mill. It is the responsibility of management to operate as close as realistically possible to that point.

As economic pressures increase, one way of increasing efficiency is to increase the size of log being sawn by sorting the log inventory if necessary, or not buying small logs. The detrimental effect of cold temperatures is also minimized by sawing only larger logs. The mill operator then has a readily available method of adapting to poor market conditions and cold winters—providing he can expect the market to get better in order to make sawing the smaller logs in his inventory profitable if he has no alternative method of utilizing them.

Thus, with this type of information available, the mill operator is in a position to make decisions and establish policies consistent not only with current economic conditions but also with the physical limitations of men and equipment. The relationships computed are valid only for the mill studied, but the principles derived should have broad application.

Wood-Aluminum Beams Within and Beyond The Elastic Range[1]

I. Rectangular Sections

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WOOD IN PERMANENT COMBINATION with other materials, or with other forms of wood, has attained considerable importance in various fields of application. Such composite constructions are intended to provide improvement in stiffness, strength, surface quality or dimensional stability, and there are often other advantages to such combinations, including improved resistance to weather, decay, or fire.

A frequently used example of this type of construction is aluminum-faced wood, which is found today in a variety of structures and products. This study was undertaken in order to analyze the mechanical interaction of the components of rectangular beams consisting of sheet aluminum bonded to the top and bottom faces of a wood core. The analytical procedure was devised to mathematically predict the strength and stiffness of these composites at proportional limit, and then compare these predictions with actual tests. Further, it was felt that mathematical analysis in the region of load and deflection beyond the elastic range was needed and could be compared with actual loads up to failure.

Review of Literature

Various studies have been made in the past on problems closely related to this one. Literature reviewed concerned mechanical properties of species (22, 23, 24)[2] various forms and shapes of wood (2, 7, 8, 9, 15, 16, 18), other materials (5, 12, 13, 17, 19, 20), laminated two-species beams (1, 3, 10, 11) and sandwich constructions (4, 6, 14, 17).

Theoretical and test results are compared of the interaction of the components of rectangular beams consisting of sheet aluminum bonded to the top and bottom faces of a wood core.

While many analytical methods used for sandwich construction consider the modulus of elasticity of the core to be insignificantly small relative to the skin, this would be unrealistic for the type of specimen in this investigation. Consequently, attention was turned instead to methods which take into account the properties of all the components as well as the geometry of the specimens. The applied moment which may be resisted by a beam of given geometry can be predicted by these methods and compared with actual test values. Stresses at various points within the composite can also be studied.

Within the elastic range, the following assumptions were made for these beams. a) The neutral axis passes through the center of gravity of the section. b) A plane section in a beam remains plane when the beam is bent. c) The modulus of elasticity for component materials is the same in both tension and compression. d) Stress at any point can be found by multiplying strain due to deformation by the corresponding modulus of elasticity of the layer.

In analyses based on the above assumptions, there arise three calculations of moment: 1) the actual applied moment; 2) the prediction of applied moment based on the known properties of the components; and 3) The internal resisting moment calculated from the determination of stress levels attained in various parts of the composite during test. In the equations used here, the core bending modulus of elasticity was used for computing the resisting moment attributable to the wood portion of the composite. This seems reasonable, in view of the type of loading employed and the relative position of the core within the laminate.

Beyond the elastic range, the previously mentioned assumptions become more or less invalid. Ductile mate-

[1] Second-place winner in the 1961 Wood Award competition. This research is part of a comprehensive study being conducted at the Yale School of Forestry in cooperation with The Office of Naval Research, Dept. of Navy, under contract Nonr. 609(13), Project NR 330-001, Properties of Tropical Woods.

[2] Numbers in parentheses refer to Literature Cited at the end of this report.

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Fig. 1.—Shown is the static beam test of the composite.

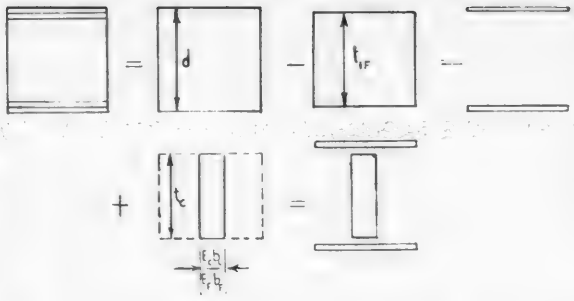

Fig. 2.—Shown is the derivation of mathematically equivalent all-aluminum section from actual wood-aluminum composite section.

rials, as aluminum, undergo rapid changes in stiffness in this region of plasticity; wood shows a decrease in bending stiffness which is initially due to a lower proportional limit for those fibers under compressive stress than those under tensile stress. Thus, the secant modulus of elasticity changes continuously as a composite is loaded in the plastic deformation range.

Various investigators (1, 3, 10, 16, 18) have developed approximate analyses for wood beams and two-species beams as the point of rupture is approached. In this work a method believed useful for plastic analysis of composites of wood and aluminum was devised. It was used for the investigation of the composites from the elastic limit to the point of failure, which we here define as the point at which either a) the compression facing folds or wrinkles, or b) the tension facing fractures or undergoes such extreme plastic strain as to delaminate. Some change may have occurred in the core prior to either of the failure criteria, such as visible compression wrinkles, but these beams typically do not fail abruptly, and their maximum strength is governed primarily by the facing.

Preparation of Specimens

The specimen size selected for this experiment was a 16-inch long beam, consisting of a wood core machined to nominal 1.0-inch width by 0.9-inch depth, to which were bonded facings of 52S–H34 aluminum alloy, each face nominally 1-inch wide by .025-inch thick. The growth rings of the core were aligned perpendicular to the metal faces.

The properties of the core woods were ascertained by representative sampling of the same planks used to supply core material for the composite beams. These test specimens were of the same size (1.0 by 0.9 by 16 inches) as the cores used in the composites, and were conditioned to equilibrium in a room kept at 73° F and 50 percent relative humidity prior to testing.

The properties of the aluminum alloy were taken from the *Metals Handbook* (19), and no verification was made.

A two-step adhesive system was used, consisting of a casein-latex primer, Casco NT–442, for the metal facings and a resorcinol, Cascophen RS–216, for bonding the primed metal to the wood. A 10 percent solution of sodium metasilicate was used for metal cleaning. Composites also underwent 73° F. and 50 percent relative humidity conditioning. A total of five specimens per core species was prepared.

Testing

Testing of Core Woods: The eight species used in this study were balsa *(Ochroma lagopus* Sw.), cativo *(Prioria copaifera* Gris.), cedro branco *(Cedrela Huberi* Ducke), basswood *(Tilia* sp.), itaúba *(Mezilaurus itauba* Taub.), hickory *(Carya* sp.), British Guiana courbaril *(Hymenaea Davisii* Sandw.), and kaneelhart *(Licaria cayennensis* Kosterm.)

Two separate lots of basswood, taken from different planks, were used. Test values for the two planks were recorded separately. A separation was also made of heartwood and sapwood for British Guiana courbaril, as the two types had different properties.

Properties of the core woods, by the methods of ASTM D143–52, are shown in Table 1. Tests were conducted on a Baldwin universal testing machine.

From every beam a section was removed as close to the bending fracture as possible in order to ascertain the exact moisture content and specific gravity. For purposes of calculation of the theoretical properties of the composites, the average strength properties of these core samples were adjusted for moisture content and specific gravity to the actual levels of moisture content and specific gravity prevailing in the cores of the composites.

Testing of Composite Specimens: Static-bending tests were conducted on the composite specimens in the same manner as for the core wood specimens. A 14:1 span-depth ratio was maintained. Core samples were removed near the break for moisture content and specific gravity determination.

A photograph of the composite beam test is shown in Figure 1.

The specimen geometry for these composites was designed with the intention that the proportional limit stress in the facings would be reached before the proportional limit stress in the core, in order to develop the maximum resisting moment. Above the proportional limit, an increased proportion of load was taken by the wood core. This was inevitable due to the ductility of the aluminum facing material.

Methods for Beam Analysis

We can approach the problem of analyzing the strength of a composite from two standpoints, which for want of a better description might be termed the practical and the theoretical. The practical uses the known geometry, previously determined modulus of elasticity of the composite, and actual applied moment at the proportional limit and at rupture respectively. It is possible to calculate the actual stresses at each point of the layers in the composite. The theoretical uses the known geometry and previously determined stresses at both proportional limit and rupture and the

moduli of elasticity of the component. It is possible to calculate the applied moment which should theoretically be borne by the beam at the limit of proportionality and at the point of rupture.

In the practical, it is necessary to use test data to locate stress magnitudes; in the theoretical, the test results of applied load can be predicted if the stresses in the components can be assumed or computed with accuracy.

The assumption that certain preupposed stress levels are reached, at the proportional limit for instance, is open to question because of the variability of both the metal for the facings (5) and the woods used as core materials. By careful selection and matching an attempt was made to minimize the core wood variability. Adjustments for a) specific gravity and b) moisture content, where the difference was more than one-half percent, were made according to well-accepted procedures (4, 21).

In the following discussion, space prohibits the mention of the analysis for shear in the composites. None of the composites in this series of tests failed by shear.

Prediction of Properties at the Limit of Proportionality: The method used for ascertaining proportional limit bending loads and stresses is derived in much the same manner as the flexure formula itself. For a rectangular beam, areas within the cross-section are weighted according to their distances from the centroid when the moment of inertia is computed.

$$I = b \int_{-\frac{d}{2}}^{\frac{d}{2}} y^2 dy$$

In a composite made up of rectangular components, each component's moment of inertia can be most simply found by the parallel axis theorem.

$$I = \frac{bd^3}{12} + (bd)y^2$$

In a composite beam these areas are also weighted according to their respective moduli of elasticity to obtain a total stiffness factor.

$$EI = \Sigma E_i I_i$$

so that the bending moments at any point are governed according to the relation

$$M = \frac{\sigma_y EI}{yE_y}$$

where y is the distance from the neutral axis (here coincident with the centroid) to the point at which stresses are being examined. As a subscript in σ_y and E_y it represents stress and modulus of the layer of the composite at the point under study. At the surface, $y = \frac{d}{2}$.

Earlier mention was made of a "practical" and a "theoretical" approach to composite beam analysis, and some note must be made here of the effect which the two approaches have on the value of EI. The "theoretical" value of EI is the one noted above, which for these beams is:

$$[EI]_T = E_{F_1} I_{F_1} + E_c I_c + E_{F_2} I_{F_2}.$$

After the composites are tested, and load-deflection curves thereby provide a value of modulus of elasticity for the composite, an actual value of EI is available:

$$[EI]_A = E_A [I_{F_1} + I_c + I_{F_2}]$$

wherein E_A is the tangent modulus of elasticity in bending, taken from the load-deflection diagram. This actual value was used in the "practical" analyses.

Using the procedure given to ascertain the theoretical value of EI, which we can designate $[EI]_T$, the equivalent theoretical modulus for a composite may be found from the expression

$$E_T = \frac{[EI]_T}{I_F + I_c}$$

which, when expanded, can be written in the form

$$[EI]_T = \frac{E_F\left(\frac{b_{F1} + b_{F2}}{2}\right)}{12}\left[d^3 - t_{IF}^3 + \left(\frac{E_c}{E_F}\right)\left(\frac{b_c}{\frac{b_{F1} + b_{F2}}{2}}\right) t_c^3 \right]$$

wherein b = width, with subscripts F1, F2 and C for the two facings and the core

d = total composite thickness

t_{IF} = total thickness except for facings

t_c = thickness of core

This represents a solid rectangular beam of aluminum whose stiffness has been reduced by modification in the moment of inertia of parts of its area. These parts, occupied by glue line and core, have lower moduli of elasticity and perhaps not exactly the same width. The adjustments to compensate for these differences are reflected in the above equation. The glue line is considered to contribute nothing to stiffness. Analytically, the equation can be thought of as representing an equivalent all-aluminum beam derived in the sequence shown in Figure 2.

Methods Used to Predict Leads and Analyze Stresses Beyond the Proportional Limit: Recent studies (1, 3) give improved methods for the analysis of two-species wood beams in the plastic deformation range. However, neither these methods nor commonly-used elastic equations were found satisfactory for these wood-aluminum specimens, and new methods had to be developed.

The aluminum alloy used for the facings has a tension stress-strain curve as shown in Figure 3. In contrast, a typical tension stress-strain diagram for wood is approximately linear nearly to rupture.

In a composite beam, bending loads which cause stresses in the facings to rise above proportional limit thereby

Table 1.—STRENGTH AND ELASTIC PROPERTIES OF CORE WOODS USED

Species	Heart- or sap-wood	Spec. Grav. O.D. Basis	Moisture Content, %	Replicates	Stress at Prop. Limit Extreme Fiber, lb. per sq. in.	Modulus of Rupture, lb. per sq. in.	Flexural Modulus of Elasticity lb. per sq. in.	Maximum Crushing Strength lb. per sq. in.
Balsa	S	.08	7.4	5	606	1,172	208,000	840
Cativo	S	.35	10.1	6	3,958	6,394	650,600	3,794
Cedro Branco	H	.37	10.6	5	5,719	9,204	1,304,500	5,996
Basswood								
Plank #1	S	.38	6.5	4	5,624	9,426	1,279,900	5,888
Plank #2	S	.41	6.6	4	8,363	11,828	1,455,600	6,985
Itaúba	H	.59	8.8	4	6,730	11,345	1,536,900	7,551
B. G. Courbaril	S	.79	8.2	4	11,148	23,105	2,969,200	10,181
B. G. Courbaril	H	.86	8.7	4	14,967	27,017	3,416,000	13,918
Hickory	S	.92	9.5	6	10,048	24,561	2,908,200	12,459
Kaneelhart	H	.97	8.8	4	20,508	30,074	3,365,300	17,553

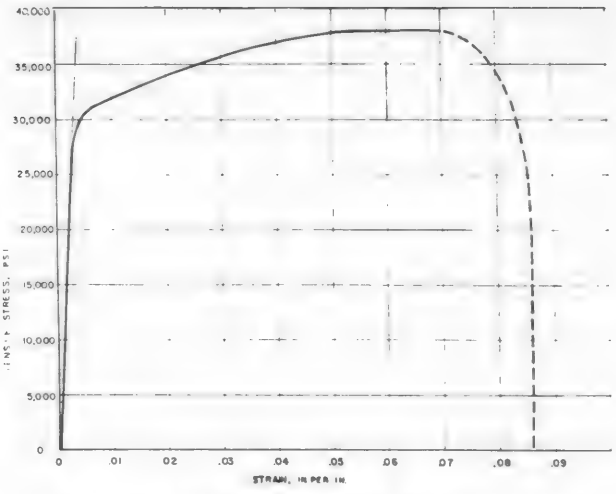

Fig. 3.—The tensile stress-strain curve for aluminum alloy 52S–H34 (5052–H34).

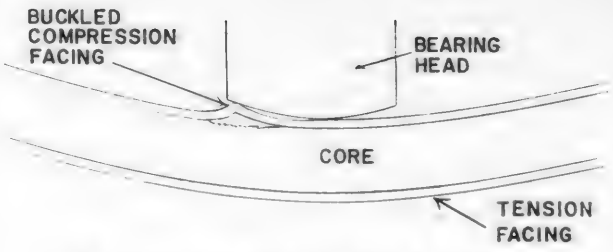

Fig. 4.—Failure of composite by buckling of compression side facing.

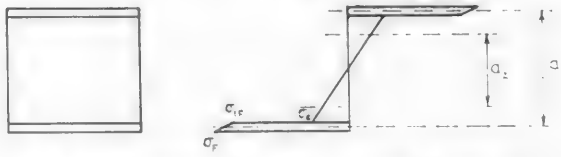

Fig. 5.—Force moment arms in composite at proportional limit.

cause the facings to deform plastically. This results in continuous changes in the secant moduli of elasticity for the composite and coincidentally for its metal and wood components. The most rapid secant modulus change occurs in the facings. This change causes progressively greater proportions of the total load to be shifted to the wood core as the stress in the facing increases to what metallurgists refer to arbitrarily as "yield point" stress, a stress at 0.2 percent offset on the stress-strain diagram (see Figure 3). For the alloy used here, this is approximately 31,000 psi at 75° F.

Failure of the composite most commonly occurs in the manner shown in Figure 4. The separation failure is in the wood, just below the adhesive line. At this point, the surface fibers of the wood have insufficient strength to stabilize the compression facing under the high load. Beyond this point, the 3-ply laminate becomes a 2-ply laminate. However, reasonably accurate predictions of beam behavior in the plastic deformation range up to the point where failure occurs were devised.

One of the first considerations is the location of the neutral axis in the composite between proportional limit and failure. The most extreme change it could undergo from its original assumed position at the beam center would be at failure, where the maximum compression force which could be exerted by the core alone, after compression skin buckling, would have to be equated to the tension force exerted by the aluminum tension facing and that part of the core in tension. This condition of equilibrium is found by the equation

$$n = \frac{1850 + R(d - t_F)}{d(2C + R)}$$

which is derived from

$$F_C - F_T = 0$$

$$C(nd) - \frac{1}{2}R(d - t_F - nd) - t_F(\sigma_{U.F.}) = 0$$

where

d = total thickness of composite beam
t_F = thickness of tension facing
$\sigma_{U.F.}$ = ultimate strength of tension facing (37,000 psi.)
C = maximum core compressive strength
R = modulus of rupture of core
n = position of neutral axis, expressed as a percent of the total depth of the beam from the top surface.

Values obtained by this computation are shown in Table 2. These values therefore represent extreme values below which the axis could not go without exceeding one of the three failure stresses (see Figure 8).

Since the actual value will be smaller than this latter value, it is evident from Table 2 that in two species, itaúba and kaneelhart, the compressive strength of the core is so high that if it exerted its full maximum strength after compression skin failure, as shown idealized in the last diagram of Figure 8, the composite beam would require more than half of its total depth to be in tension in order to balance this high compression force per unit area.

Such a conclusion is well borne out by the sequence of events which took place in the testing of composites with cores of these two species. As with all composites, visible changes in the core, such as compression wrinkling or tension fractures, may take place before the failure (i.e., compression skin buckling or tension skin rupture) of the composite beam These changes in the core, particularly compression wrinkles, do not typically occur at maximum load.

In every composite whose core was one of these two species, tension fractures in the core, rather than compression wrinkles, preceded the failure of the composite beam.

It can be seen from the values in Table 2 that little shift can be experienced by the neutral axis even under extreme conditions. Therefore, we can assume the neutral axis to remain very near the center of the beam under load up to the point of failure, and consider it to be at the center.

With the neutral axis fixed at center, we can study the approximate behavior of a beam as shown in Figure 8 in the plastic deformation range by examining the load-deflection relationship of the composite at points which correspond to the load-deflection diagrams of the wood core species control samples. For example, a deflection D in the composite is checked on the load-deflection diagrams of each of the samples, and from these diagrams, average values for the core material are computed for secant modulus of elasticity, and for extreme fiber stress in bending at that deflection reading, always assuming that: 1) plane sections remain plane, 2) moments of inertia are not changed, and 3) the neutral axis remains at the center of the beam.

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With these assumptions, which are admittedly inaccurate, the usual formulas

$$\sigma_D = \frac{1.5\ PL}{bd^2} \text{ and Sec. } E_D = \frac{PL^3}{4Dbd^3}$$

are used for stress and secant modulus of elasticity, respectively, at deflection D. In these equations.

P = load at deflection D
L = span
b = width of specimen
d = depth
D = deflection of beam

Once stress in the wood surface of the samples at a given deflection is known, it can be assumed for the wood surface in the composite, after adjustments for differences in specific gravity and moisture content are made for the wood core. Then the secant modulus of the facings can be ascertained from the relationship

Compos. $E_D[\Sigma I_i] = [EI]_F + [EI]_c$

wherein

Compos. E_D = Actual secant modulus of elasticity of the composite beam at a deflection of D inches.
$\Sigma I_i]$ = sum of the moments of inertia of the components.
$[EI]_F$ = stiffness factor of the two facings.
$[EI]_c$ = stiffness factor of the core.

As usual the stiffness factors are computed by the weighted parallel-axis theorem,

$$[EI] = \sum_{i=1}^{i=3} E_i I_i + b \sum_{i=1}^{i=3} E_i t_i y_i^2$$

wherein

t_i = thickness of a lamina
y_i = distance from the centroid of a lamina to neutral axis.

Since all elements of the above two equations are known save the E_i of the facings, the secant modulus of the aluminum in the composite at the stated deflection, this value will be solved for in these equations.

Assuming the adjusted stress in the core of the composite has reached the same level as σ_D above when the composite is deflected D inches, a value can now be obtained for the stress within the facings from

$$\sigma_F = \frac{y_F E_F}{y_c E_c} \sigma_D'$$

in which

σ_F = stress in facings at a deflection D of the composite beam
y_F = distance to extreme fiber of facing from neutral axis
y_c = distance to extreme fiber of core from neutral axis
E_c, E_F = secant moduli of elasticity at deflection D
σ_D' = adjusted assumed stress at extreme fiber of core when composite beam deflection is D inches.

Table 2.—THEORETICAL MAXIMUM POSSIBLE DEPTH OF NEUTRAL AXIS FROM TOP SURFACE OF COMPOSITE AT FAILURE*

Core Species	Specimen Number	Maximum depth of neutral plane as percent of total depth
Cativo	1	.5617
	2	.5869
	3	.5617
	4	.5671
	5	.5726
Cedro Branco	1	.5196
	2	.5229
	3	.5215
	4	.5067
	5	.5141
Basswood (Core from Plank #1)	1	.5383
	2	.5376
	3	.5337
Basswood (Core from Plank #2)	1	.5079
	2	.5206
Itaúba	1	.4913
	2	.4909
	3	.4891
	4	.4904
	5	.4910
B. G. Courbaril (Sapwood)	1	.5646
	2	.5622
B. G. Courbaril (Heartwood)	1	.5149
	2	.5153
	3	.5151
Hickory	1	.5222
	2	.5221
	3	.5228
	4	.5227
	5	.5224
Kaneelhart	1	.4790
	2	.4794
	3	.4857
	4	.4810
	5	.4793

*In this table, the point of failure is considered to be coincident with maximum load.

It is to be noted that maximum deflection of the solid wood test specimens is not necessarily used when studying maximum deflection of wood-core composites. This is important.

Since maximum deflection of a composite typically exceeds maximum deflection of solid wood core samples, a calculation of secant modulus at failure for wood core samples would often yield an unrealistically high value for substitution into a composite beam analysis. Secant moduli decrease as deflections increase beyond the limit of proportionality.

Although in this study the assumed stress for the wood core is a bending stress rather than a tensile stress, as assumed in the analysis of Curry (1) and Ethington (3), it might be pointed out that the action of the wood within the composite is quite similar to the action of the samples for which bending stresses are computed. The maximum stress in bending is generally assumed to be on the tension side of the wood beam, or wood core, as the case may be. The *Wood Handbook* (4) recommends the use of modulus of rupture values in the absence of tensile test data.

The values for stress in facings and core can now be checked by computing the internal resisting moment of the composite beam against the actual known applied moment. All of this is demonstrated in "Results and Discussion."

Results and Discussion

Elastic range: The average values for applied moment and modulus of elasticity for each type of composite specimen at proportional limit are shown in Table 3. Both actual values and values predicted by the "theoretical" analysis are given. The "practical" analysis consists of taking the actual applied moment as given in Table 3, and from this determining the stresses which existed at various levels in the composite at that point. The stresses thus computed are then checked for accuracy by using them to compute the total internal resisting moment, which should, of course, check closely with the actual applied

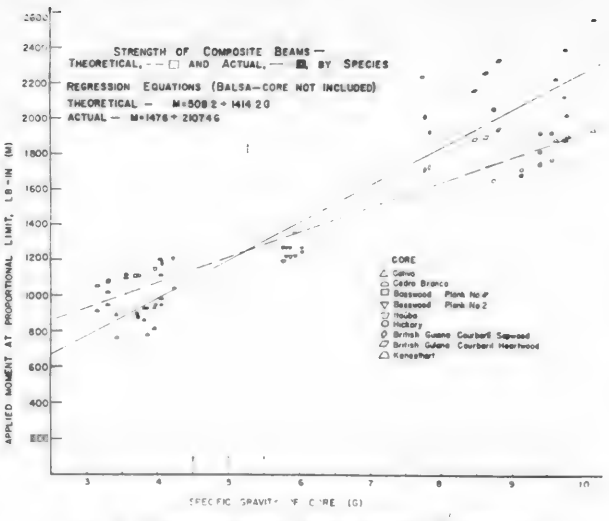

Fig. 6.—Theoretical and actual strength of composite beams.

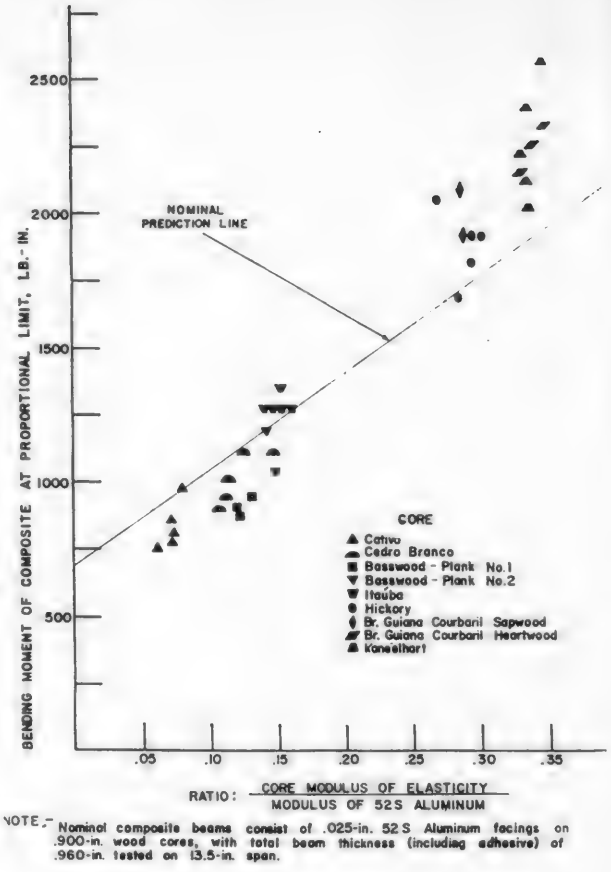
BENDING MOMENT OF COMPOSITE AT PROPORTIONAL LIMIT, LB.-IN.
NOMINAL PREDICTION LINE
CORE
Cativo
Cedro Branco
Basswood - Plank No.1
Basswood - Plank No.2
Itaúba
Hickory
Br. Guiana Courbaril Sapwood
Br. Guiana Courbaril Heartwood
Kaneelhart
RATIO: CORE MODULUS OF ELASTICITY / MODULUS OF 52S ALUMINUM
NOTE:- Nominal composite beams consist of .025-in. 52S Aluminum facings on .900-in. wood cores, with total beam thickness (including adhesive) of .960-in. tested on 13.5-in. span.

Fig. 7.—Effect of core modulus on strength of composite beams.

moment. Total internal resisting moment is obtained from the equation
I.R.M. $=$ (F.T.) (a_1) $+$ (C.T.) (a_2)
where

F.T., C.T., are total tension forces exerted by facing and core respectively a_1, a_2, are moment arms as shown in Figure 5.

The computed average face and core stresses and internal resisting moments for each type of specimen at proportional limit are given in Table 4.

Since the load-carrying capacity of beams whose cores are weak is increased in greater proportion than the capacity of beams with strong cores, it might be expected that the discrepancy percentage-wise between predicted composite modulus of elasticity and the apparent modulus derived from the tangent line of the load-deflection curve plotted from a center-loaded test would be greater for beams having weak cores. As is evident in Table 3, this is actually the case. The higher percentage increase of total load which can be sustained by a weak-core composite means a higher percentage increase in vertical and horizontal shear. This in turn is apparently reflected in higher shear strains, causing an especially low value for tangent modulus in composites of this type. A similar relationship is evident for strength of composites. Weak-core composites were predicted to have greater strength than they had, while strong-core composites were predicted to have less strength than they actually had. Shear effects play a role here, even though the beams do not fail in shear. Another influence is the fact that denser woods offer greater buckling resistance as supporting fibers to the aluminum skins.

A graph (Figure 6) has been prepared showing actual applied moment at proportional limit for each composite related to the specific gravity of its core. Predicted values are also plotted.

More significantly, however, another graph (Figure 7) shows the effect of core modulus of elasticity on strength of composites at proportional limit. In testing these specimens, the limit of proportionality in the aluminum was reached, as planned, before that of the wood core. Therefore, the composite proportional limit loads and moments were in general proportional to the core moduli of elasticity, since at that point all cores took load within their elastic ranges and were not stressed to their elastic limits.

Plastic Range: Predicted and actual values for average maximum bending moment are given in Table 5. Predictions were made by the same methods that were used for the elastic range. The inaccuracy of the predictions indicates the need for special methods to predict these values for wood-aluminum laminates.

Three beams were selected for detailed study. The core woods were cativo, itaúba, and British Guiana

Table 3.—AVERAGE THEORETICAL AND ACTUAL VALUES FOR APPLIED MOMENT AND MODULUS OF ELASTICITY FOR COMPOSITES

Core Species	Applied Moment at Proportional Limit, lb.-in.		Tangent Modulus of Elasticity, psi	
	Theoretical	Actual	Theoretical	Actual
Balsa	790	see footnote	1,760,200	1,439,200
Cativo	925	835	2,166,000	1,877,800
Cedro Branco	1100	1020	2,606,500	2,146,500
Basswood (Core from Plank #1)	1120	905	2,615,400	2,191,000
Basswood (Core from Plank #2)	1195	1115	2,793,600	2,497,000
Itaúba	1220	1280	2,866,300	2,474,600
B. G. Courbaril (Sapwood)	1725	2010	4,033,500	3,599,800
B. G. Courbaril (Heartwood)	1910	2250	4,479,700	4,016,100
Hickory	1735	1835	4,048,100	3,634,500
Kaneelhart	1905	2270	4,455,200	3,947,400

Note: Problems in testing arose which gave incorrect results for the proportional limit moments for beams with cores of this species. The average for these incorrect data is therefore not included. High bearing load induced crushing. (See concl.)

courbaril heartwood, respectively. An illustration of the analysis will be given here for the courbaril-core beam, whose load-deflection diagram is shown in Figure 9.

In order to analyze the stresses existing in face and core in the region beyond proportional limit, three points of deflection in the plastic deformation range were considered:

D = .150 in.
D = .175 in.
D = .200 in.

As outlined previously, the first step was to ascertain the core stress and core secant modulus of elasticity at the deflections indicated. These values were the average of all core material replications. Values obtained (adjusted for specific gravity to correspond with core of the composite) were:

Deflection, in.	Stress in Core, psi	Secant Modulus of Core, psi
.150	16,990	3,334,400
.175	19,310	3,245,200
.200	21,270	3,129,200

Next, secant moduli for the composite and the facings were computed by the method described

Deflection, in.	Secant Modulus of Composite, psi	Secant Modulus of Facings, psi
.150	3,751,900	6,090,000
.175	3,633,000	5,823,000
.200	3,498,100	5,571,900

Using these secant moduli for faces and cores, stresses in the facings were determined.

Deflection, in.	Facing Stress, psi-Outer Surface	Facing Stress, psi-Inner Surface
.150	32,910	31,200
.175	36,690	34,780
.200	41,160	39,020

Finally, a check of the internal resisting moment with the stress levels at deflections 0.150, 0.175 and 0.200 was made, with the following results.

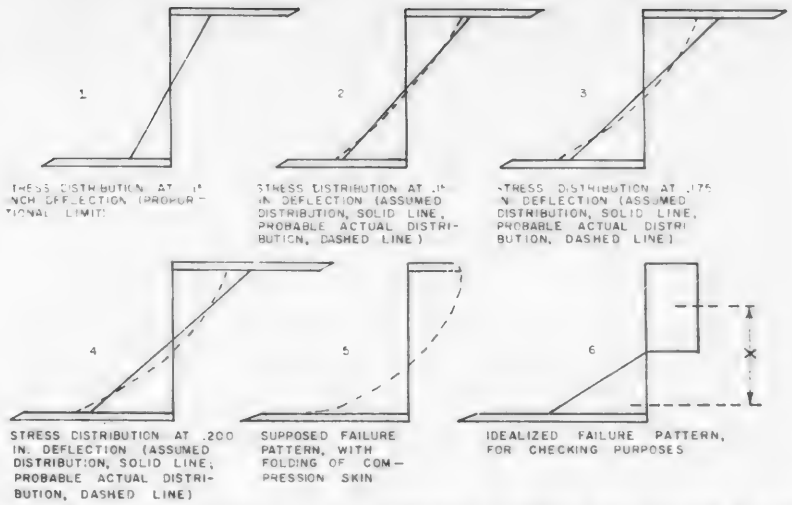
1
2
3
4
5
6
STRESS DISTRIBUTION AT .1 INCH DEFLECTION (PROPORTIONAL LIMIT)
STRESS DISTRIBUTION AT .1 IN. DEFLECTION (ASSUMED DISTRIBUTION, SOLID LINE, PROBABLE ACTUAL DISTRIBUTION, DASHED LINE)
STRESS DISTRIBUTION AT .175 IN. DEFLECTION (ASSUMED DISTRIBUTION, SOLID LINE, PROBABLE ACTUAL DISTRIBUTION, DASHED LINE)
STRESS DISTRIBUTION AT .200 IN. DEFLECTION (ASSUMED DISTRIBUTION, SOLID LINE, PROBABLE ACTUAL DISTRIBUTION, DASHED LINE)
SUPPOSED FAILURE PATTERN, WITH FOLDING OF COMPRESSION SKIN
IDEALIZED FAILURE PATTERN, FOR CHECKING PURPOSES
x

Fig. 8.—Shown are stresses at different deflections in composite beam consisting of British Guiana courbaril core .902 inch thick and 1.000 inch wide with aluminum facings .025 inch thick and 1.002 inches wide. The total beam thickness including adhesive lines is .957 inch.

	Deflection .150"	Deflection .175"	Deflection .200"
Tension Force of Facing (F.T.), lb.	657	733	822
Tension Force of Core (C.T.), lb.	3831	3903	4796
Internal Resisting Moment (I.R.M.), lb.-in.	2914	3029	3648
Actual Applied Moment (A.A.M.), lb.-in.	2707	3058	3368
Error in calculated Internal Resisting Moment	+7.65%	−0.95%	+8.33%

These results indicate that the levels of facing and core stress which were computed were not too different from the actual case, in spite of the fact that the beam dimensions changed somewhat during plastic deformation.

A rather complete picture of the behavior of this beam can thus be proposed. In Figure 8, Diagram 1 shows the stress distribution at proportional limit. Diagrams 2, 3, and 4 show the distribution in the first, or predictable, region of the plastic deformation range as deflection of the beam increases to three different levels beyond the elastic limit. Considering the neutral axis to remain at the center of the beam and the core tension and compression areas as equal-area triangles is an idealized simplification which does not greatly affect the results.

In the second region of the plastic deformation range, which occurs after the compression facing has buckled, it is difficult to perceive exactly how much stress exists in the wrinkled facing. Diagram 5 of Figure 6 represents one possibility; there are many others.

The greatest possible moment which could be resisted by the area in compression at this condition is represented ideally by Diagram 6 of Figure 8. If all the area above the neutral axis including that thickness taken up by the buckled skin exerted core maximum compressive stress, then this area could be represented by a force extend to the resultant of the core tension and facing tension forces. Theoretically the location of the neutral axis for this extreme condition of failure is the appropriate Table 2 value, where compression forces balance the rectangle. Its moment arm (x) would resultant of the maximum tensions in facing and core.

For the other two composite beams studied, with cativo and itaúba cores, computed moments agreed within 18.5 and 10.7 percent, respectively, with actual test values in the plastic range.

Conclusions

The stiffness and strength of wood-aluminum composite beams may be reasonably well predicted up to the failure point, where failure is defined as a) folding, wrinkling, or buckling of the compression facing, or b) extreme plastic strain of the tension facing, causing fracture or delamination.

Within the elastic range, equations which ignore shear effects will predict, for composite beams of the type and size tested, modulus of elasticity values which are 10 to 20 percent too high, the greater discrepancy occurring in beams with low density cores. For other beam configurations involving combinations of wood and aluminum, other factors might apply.

Proportional limit strength predictions are most accurate for this type of beam when the core is a medium-density species. Predicted moments are low for dense woods and high for light species.

The proportional limit will be apparently lowered if the bearing load attained in approaching proportional limit bending moment for the composite induces crushing of the wood core.

Stress levels in the aluminum faces may exceed published values for the alloy used, a phenomenon which has been previously observed in wood-aluminum composites (6). This can be true in both the case of stress at proportional limit and stresses within the plastic deformation range.

Table 4.—COMPUTED STRESSES AND INTERNAL RESISTING MOMENTS IN COMPOSITES AT PROPORTIONAL LIMIT

Core Species	Extreme Fiber Stress in psi for		Internal Resisting Moment, lb.-in.
	Facings	Core	
Cativo	30,320	2,045	965
Cedro Branco	32,620	3,700	1,240
Basswood (Core from Plank #1)	27,985	3,280	1,080
Basswood (Core from Plank #2)	30,375	4,140	1,270
Itaúba	35,420	5,055	1,485
B. G. Courbaril (Sapwood)	37,800	10,270	2,250
B. G. Courbaril (Heartwood)	38,645	12,345	2,545
Hickory	35,210	9,560	2,100
Kaneelhart	39,020	12,390	2,560

Table 5. —AVERAGE THEORETICAL AND ACTUAL VALUES FOR MAXIMUM BENDING MOMENT

Core Species	Theoretical Maximum Bending Moment (at failure), lb.-in.	Actual Maximum Bending Moment, lb.-in.
Cativo	1,180	1,835
Cedro Branco	1,405	1,815
Basswood (Core from Plank #1)	1,430	1,895
Basswood (Core from Plank #2)	1,525	2,055
Itaúba	1,555	2,740
B. G. Courbaril (Sapwood)	2,200	3,845
B. G. Courbaril (Heartwood)	2,440	4,510
Hickory	2,220	4,130
Kaneelhart	2,430	5,050

Composite beam strength at proportional limit is directly proportional to core modulus of elasticity. Core and facing secant moduli control strength in the plastic range to a degree, but core rupture seems to depend on maximum allowable strain.

As the data in Tables 1, 3, and 5 indicate, beams with low density cores show more proportionate increase in stiffness by the addition of the facing reinforcement, whereas beams with high density cores show more proportionate increase in strength.

For plastic design of wood-aluminum composite beams, a procedure similar to standard methods used in the reinforced concrete industry is recommended: a) initially plan an approximate design based on experience with composites of similar composition;

b) test one composite beam of the type under consideration to determine plastic load-deflection characteristics;

c) test material of the same core species and dimensions to determine core strength and stiffness at similar plastic deflections; if these deflections are beyond the rupture of the core, select the nearest available values;

d) adjust core properties for moisture content and specific gravity, and use these data to compute facing secant moduli, face stresses, and expected loads at the level desired;

e) adjust final design if necessary to agree with test results.

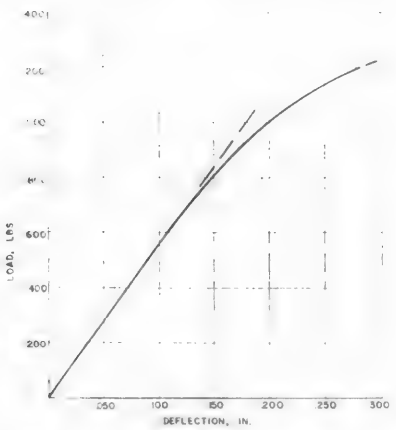

Fig. 9.—Load-deflection of composite with core of British Guiana courbaril heartwood.

Literature Cited

1. Curry, W. T. 1955. Laminated beams from two species of timber. Theory of design. Forest Products Research Special Report No. 10. Dept. of Scientific and Industrial Research (U.K.) London. 41 pp.
2. Dietz, A. G. H. 1942. Stress-strain relations in timber beams of Douglas fir. American Society for Testing Materials. Bulletin No. 118: 19–27.
3. Ethington, R. L. 1960. Stiffness and bending strength of beams laminated from two species of wood. Report No. 2156. U. S. Forest Products Laboratory.
4. Forest Products Laboratory. 1955. Wood Handbook. Agric. Handbook No. 72. U. S. Dept. of Agriculture, Forest Service. 528 pp.
5. Gaylord, E. H., Jr. and C. N. Gaylord. 1957. Design of streel structures including applications in aluminum. McGraw-Hill Book Company, Inc. New York. 540 pp.
6. Gibbons, H. B. 1947. Experiences of an aircraft manufacturer with sandwich material. Society of Automotive Engineers Annual Meeting, Detroit, Jan. 6–10, 1947, Preprint.
7. Ivanov, Yu. M. 1958. The strain behavior of wood. For. Prod. J. 8 (11): 41-A.
8. Kellogg, R. M. 1959. The strain behavior of wood subjected to repetitive stressing in tension parallel to the grain. Doctoral Dissertation, Yale School of Forestry. 51 pp.
9. King, E. G., Jr. 1959. The time-dependent strain behavior of wood in tension parallel to the grain. Doctoral Dissertation, Yale School of Forestry. 62 pp.
10. McKean, H. B. 1944. Mechanical properties and design procedure for glued laminated beams composed of two wood species. Univ. of Michigan School of Forestry and Conservation. Bulletin No. 11.
11. Munitions Board Aircraft Committee. 1951. ANC-18. Design of Wood Aircraft Structures. U. S. Gov't. Printing Office.
12. Munitions Board Aircraft Committee. 1950. ANC-5. Strength of Metal Aircraft Elements. U. S. Gov't. Printing Office.
13. Munitions Board Aircraft Committee. 1954. ANC-17. Plastics for Aircraft. U. S. Gov't. Printing Office.
14. Munitions Board Aircraft Committee. 1955. ANC-23. Sandwich Construction for Aircraft. U. S. Gov't. Printing Office.
15. Newlin, J. A. and G. W. Trayer. 1924. The influence of the form of a wooden beam on its stiffness and strength. II. Form factors of beams subjected to transverse loading only. Report No. 181. National Advisory Committee for Aeronautics, Washington.
16. Robinson, H. and D. W. Cooper. 1958. The ultimate strength in bending of solid timber beams. Journal of the Institute of Wood Science. No. 2: 40–65.
17. Sonneborn, R. H. (with contributions by A. G. H. Dietz and A. S. Heyser). 1958. Fiberglass reinforced plastics. Reinhold Publishing Corp. New York. 240 pp.
18. Stern, E. G. 1941. The elastic and strength properties of wood in flexure. Timber Engineering Co., Washington. D. C. 6 pp.
19. Taylor, L. (editor). 1957. Metals Handbook. American Society for Metals, Cleveland, Ohio. 1332 pp.
20. Timoshenko, S. 1955. Strength of Materials. Part I. D. Van Nostrand Company, Inc. 442 pp.
21. Wangaard, F. F. 1957. A new approach to the determination of fiber saturation point from mechanical tests. For. Prod. J. 7 (11): 410–416.
22. Wangaard, F. F. and A. F. Muschler. 1952. Properties and uses of tropical woods, III. Tropical Woods 98: 1–190 (June 1, 1952).
23. Wangaard, F. F., A. Koehler and A. F. Muschler. 1954. Properties and uses of tropical woods, IV. Tropical Woods 99: 1–187 (April 1, 1954).
24. Wiepking, C. A. and D. V. Doyle. 1944. Strength and related properties of balsa and quipo woods. Report No. 1511. U. S. Forest Products Laboratory.

Effect of Heat on the Decay Resistance of Wood[1]

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How does commercial heating, involved in certain stages of wood manufacturing or processing, affect the natural heartwood decay resistance of wood?—the Navy Department, Bureau of Ships, wanted to know.

The U. S. Forest Products Laboratory, Madison, Wisconsin, provided them with the answers. Although the heating was conducted largely under controlled laboratory conditions, a brief supplementary appraisal was made of Douglas-fir that was actually kiln dried.

HEAT IS UTILIZED AT SOME stage in the production of many wood products. For example, it is used in the kiln drying of lumber and the hot-air drying of veneer, in hot-press gluing, and in steam bending. Because the resistance of the more durable woods to decay is due to fungus-inhibitory extractives of the wood, questions arise from time to time as to whether a particular commercial heating process may reduce decay resistance by alteration or destruction of these extractives.

Inquiry in this regard was made recently by the Navy Department concerning the effects of any boat application to which several woods that are used or considered for boat building might ordinarily be subjected while the boat is under construction. This inquiry prompted the present study, in which the heartwood of nine species of wood was heated to various levels in a dry or a wet atmosphere and then tested for decay resistance by a standard laboratory procedure.

Experimental Procedure

Selection of Wood Samples: Dry board sections were obtained for the study from mill-run lumber of angelique *(Dicorynia paraensis)*[3], Alaska-cedar *(Chamaecyparis nootkatensis)*[4], Atlantic white-cedar *(Chamaecyparis thyoides)*, baldcypress *(Taxodium distichum)*, Douglas-fir *(Pseudotsuga menziesii)*, true mahogany *(Sweitenia* sp.), redwood *(Sequoia sempervirens)*, white oak *(Quercus alba)*, and western redcedar *(Thuja plicata)*. Where more than one board of a species was used, boards were taken from places in the stock pile sufficiently far apart that each might be safely assumed to have come from a different tree. This was done because, as a rule, the natural preservatives of a durable wood may be highly variable among different trees of the species. The numbers of boards or trees taken to represent the different woods were: Alaska-cedar and white oak, 6 to 9; angelique, 6; Atlantic white-cedar, baldcypress, redwood, and western redcedar, 1 each; and Douglas-fir and mahogany, 2 to 3. Only heartwood was retained in each case, since it is only the heartwood that had significant decay resistance.

The samples were sawed into ¾-inch cubes. Blocks to be given heat treatment and those to serve as unheated controls were always board matched.

Heating: So-called "dry" heating —in a dry atmosphere—was accomplished by placing the blocks in temperature-regulated ovens. So-called "wet" heat was applied for the most part by steaming the blocks after they had been conditioned in a humidity room to a moisture content of about 20 percent on a dry-wood basis. Steaming at 180° and 212° F. was done in an autoclave, and at higher temperatures in a small pressure-treating cylinder. The atmosphere during steam heating was considered to be essentially saturated. Temperatures above 212° were 275°, 300°, and 350° F., although not all of these were included each time. Periods of heating used in most cases were 1, 24, and 48 hours, but in a few cases additional periods of ¼, ½, and 6 hours were included.

This was not a continuous study but was conducted as three separate investigations. All temperatures and heating periods were not applied to each

[1] This study was made in cooperation with the Navy Department, Bureau of Ships. Approved for publication June, 1961.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] For samples of angelique, the writers are indebted to French Guiana Timbers, Inc., New York.

[4] For samples of Alaska-cedar, the writers are indebted to: Canadian Forest Products, Elburne Sawmills Division, Vancouver, B.C.; Chambers Lumber Co., Chicago, Ill.; Ehrlich-Harrison Co., Seattle, Wash.; General Hardwood Co., Tacoma, Wash.; J. Fyfe Smith Co., Vancouver, B.C.; Winde-McCormick Lumber Co., Charlestown, Mass.

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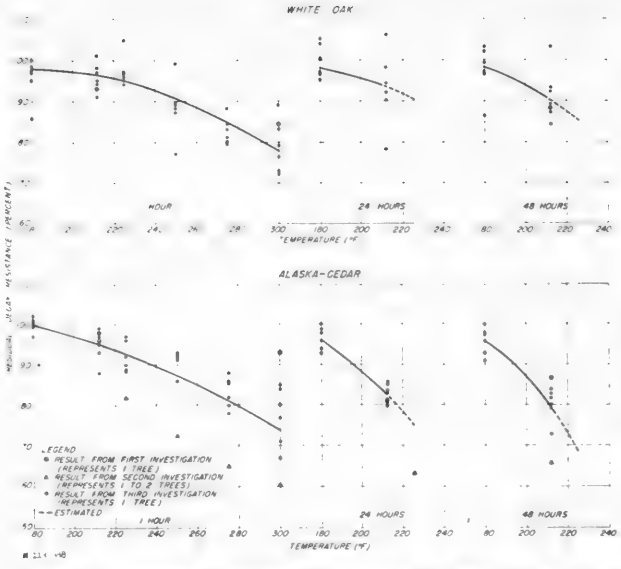


Fig. 1.—Examples illustrating the manner of graphically deriving the relation between residual decay resistance and temperature of wet heat.

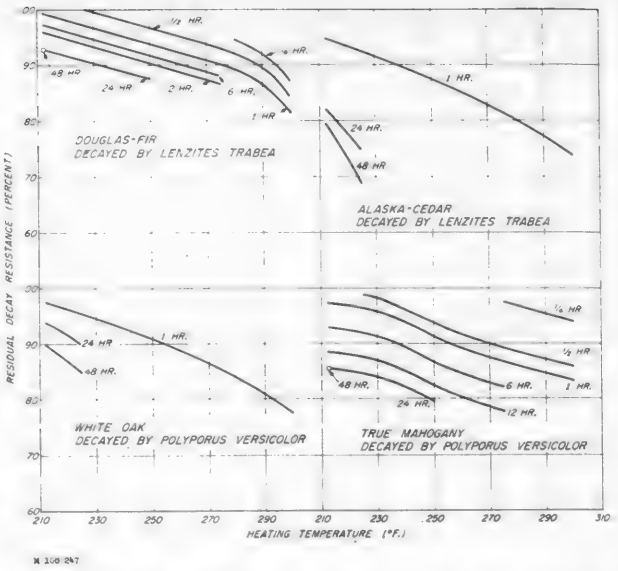


Fig. 2.—Relation between residual decay resistance and temperature of wet heat in four woods.

species. As a result, certain variations in associations of variables had to be considered in analyzing results.

Determining Decay Resistance: The variously heated and the unheated control blocks were evaluated for decay resistance by the laboratory soil-block method. This is a standard accelerated test employing pure cultures of decay fungi. French-square bottles of 8-ounce capacity were half filled with garden soil. On top of the soil in each bottle was placed a sapwood wafer ("feeder block") of pine for use with the blocks of coniferous species and of sweetgum for use with the blocks of hardwood species. The bottles thus prepared were autoclaved, inoculated with a test fungus, and incubated for 3 weeks. The ¾-inch specimens then were placed on feeder blocks, one to a bottle. These specimens had been dried, weighed, and briefly sterilized while dry by heating them in an autoclave for 15 minutes at 212° F. After 12 weeks of incubation, the blocks were removed and again dried and weighed. Drying of the blocks before and after exposure to the fungus and all incubation were done in a room maintained at 80° F. and 70 percent relative humidity. Details of the foregoing and other pertinent decay procedures were the same as prescribed by the standard ASTM test for preservatives (1)[3].

The decay fungi used throughout the study were *Lenzites trabea* (Madison 617) for assaying the softwood blocks and *Polyporus versicolor* (Madison 697) for assaying the hardwoods. These are standard test fungi, which in a large number of studies have proved their general suitability for appraising decay resistance.

Measuring Stability of Decay Resistance: The amount of decay in the test blocks during the 12-week incubation period was measured by the percentage loss in dry weight of wood. The loss in a fixed period of time also constituted a measure of the relative decay susceptibility of the wood. Conversely, the percentage of original weight retained by a block provided a measure of the decay resistance of the wood. The decay resistance was thus quantitatively calculated by:

$$\text{Index of resistance} = 100\,\frac{\text{Final dry weight}}{\text{Initial dry weight}} \qquad (1)$$

or

$$\text{Index of resistance} = 100\text{-percent weight loss} \qquad (2)$$

The effects of heating on the decay resistance of the respective woods were measured by the percentage of initial decay resistance retained by the wood after heating. This quantity, which will be referred to as the residual decay resistance or simply the residual resistance, was derived thus:

$$\text{Percent residual resistance} = 100\,\frac{\text{Final index of resistance}}{\text{Initial index of resistance}} \qquad (3)$$

The average results obtained with white oak subjected to wet heat at 212° F. are cited in Table 1 as examples of calculated data.

Results of Dry Heating

Dry heating reduced the decay resistance of the woods by comparatively small amounts (Table 2). The residual resistance did not fall below 90 percent except slightly in three instances where the temperature was elevated to 300° or 350[3] F. for 48 hours.

The insignificant reductions in decay resistance caused by dry heat do not justify distinguishing among the nine woods in this respect other than to note that angelique, baldcypress, Douglas-fir, and white oak exhibited slightly more stability of decay resistance than the other woods.

Results of Wet Heating

Trends of Heating Effect: Wet heating caused various reductions in decay resistance according to the temperature, duration of heating, and wood species. Loss of resistance in some woods was considerable with the more severe heating schedules. The relations of residual resistance to temperature were established graphically in the manner shown in Figure 1 for white oak and Alaska-cedar. The downward trends of resistance approached linearity in relation to both increased temperature (Figure 2) and increased duration of heating (Figure 3). Certain differences among the woods in rate of change caused by heating are indicated, but these cannot be viewed with too much significance because of the limited data supporting them.

Resistance of Various Woods as Affected by Wet Heating: In Table 3 are summarized the effects of wet heat involving the principal temperature-time combinations, in terms of the residual (percentage of original) resistance remaining after heating. These residuals can be used for a number of comparisons among the different woods, temperatures, and periods of heat application. Small losses of decay resistance from heating at 180° F. for periods up to 48 hours are indicated, and generally small losses at 212° F. maintained for 1 hour. The greatest losses caused by an hour of heating at 212° F. were near 10 percent (residual 90 percent) and occurred in the Atlantic white-cedar, redwood, and western redcedar. A temperature of 212° F. maintained for 48 hours caused losses of 1 to 27 percent. The severest heating, 300° F. for 1 hour, caused losses of resistance in eight of the woods amounting to 17 to 32 percent. Only the angelique remained at near normal level of resistance. The practical significance of these various percentage changes is discussed in detail later.

The relative susceptibility of the respective woods to change in decay resistance with wet heat tended to be similar for all levels of heating, as shown in Figure 4. This suggests, of course, that a wood bearing a certain relation to another with respect to change in decay resistance induced by the mildest heating tends to bear the same relation in its response to the most severe heating. It is possible, consequently, to group the woods according to their relative susceptibility to alteration by wet heat without regard to specific temperatures or periods of heating. Such a grouping, in which the species are assigned to four groups of heat susceptibility defined according to Figure 4, is as follows:

Group I (least susceptible)	Group III
Angelique	White oak
	Mahogany
	Western redcedar
Group II	Group IV
Baldcypress	Redwood
Douglas-fir	Atlantic white-cedar
	Alaska-cedar

The group placement of a particular species was determined by its occurrence at least twice in that group in Figure 4.

Besides considering the relative effect of wet heat on the different woods, it also is useful in certain connections to know how it affected the actual, or absolute, levels of resistance. For example, if the woods are rated according to the four commonly recognized classes of decay resistance—highly resistant, resistant, moderately resistant, and slightly resistant—does a certain kind of heating shift a wood entirely out of its normal class? Whether this would be likely depends on the initial or normal class as well as on the loss of resistance.

Classes of resistance to decay by the test fungi employed, before and after heating, are shown in Table 4. The classes of resistance shown in the table for the normal, unheated wood were known by reputation and from earlier testing for baldcypress (4); Douglas-fir (7) (12); oak (13); mahogany (8), and western redcedar (7) (10). The classes shown for heated woods were determined according to established levels of weight loss produced by the test fungus used, thus:

Percent weight loss in test	Index of resistance	Indicated resistance class
0–10	90–100	Highland resistant
11–24	76– 89	Resistant
25–44	56– 75	Moderately resistant
45 or more	55 or less	Slightly resistant

For most purposes, it is of no particular advantage to deal with smaller differences than are represented by these classes.

A study of Table 4 reveals that the decay resistance of none of the three woods heated at 180° F. for up to 48 hours was lowered sufficiently to take a wood out of its normal class of resistance.

At 212° F., the same was true of woods in heat-susceptibility groups I and II, but the more susceptible woods —of groups III and IV—were variously lowered in class depending upon the heating time. In those groups, heating for 1 hour lowered the resistance of all but the white oak and mahogany a half to a full class. The latter two woods remained in the resistant class. Heating at 212° F. for 24 or 48 hours seemed to have no significant further effect on the western redcedar, but it lowered the resistance of the woods of group IV an additional half to one class, and caused the first noticeable damage to the white oak and mahogany (reductions of one half to one class). Such effect as the 48-hour heating may have had beyond that produced in 24 hours was not noticeable in the woods of group III. Heating at 212° F. for 48 hours probably caused the woods of group

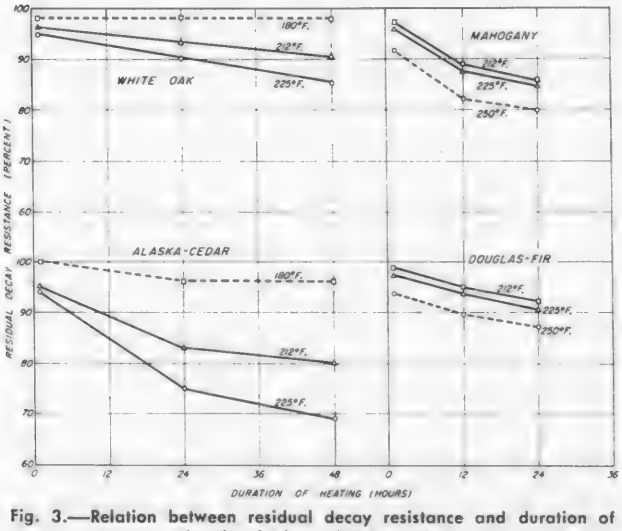


Fig. 3.—Relation between residual decay resistance and duration of heating in four of the woods.

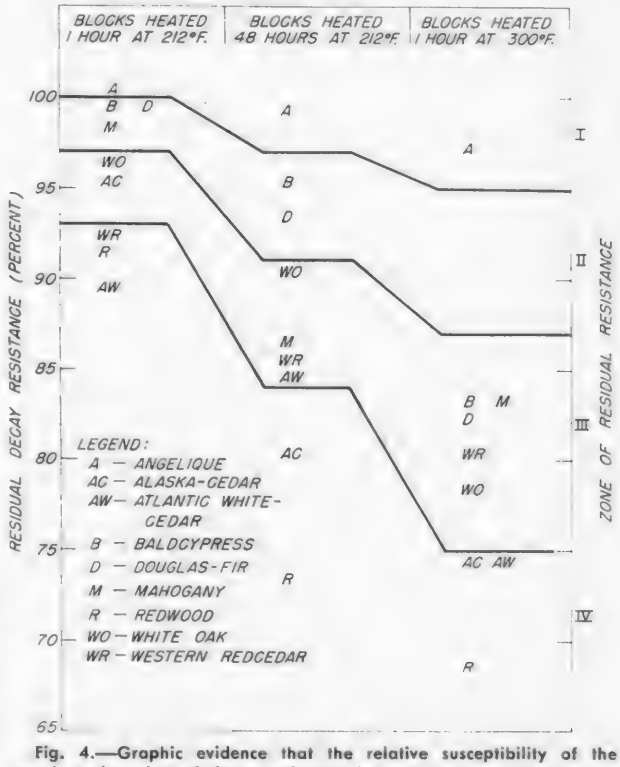


Fig. 4.—Graphic evidence that the relative susceptibility of the woods to lowering of decay resistance by wet heat was substantially independent of the severity of heating.

Table 1.—INDEX OF DECAY RESISTANCE AND RESIDUAL DECAY RESISTANCE OF WHITE OAK

Calculation	Period of heating			
	0 (control blocks) Percent	1 hour Percent	24 hours Percent	48 hours Percent
Weight loss from decay	20	23	26	27
Index of resistance[1]	80	77	74	73
Residual resistance[2]	--	96	93	91

[1]Formula (2).
[2]Formula (3).

Table 2.—RESIDUAL DECAY RESISTANCE, OR PERCENT OF ORIGINAL DECAY RESISTANCE, REMAINING IN HEARTWOOD SAMPLES OF THE NINE DIFFERENT WOODS AFTER THEY WERE SUBJECTED TO VARIOUS APPLICATIONS OF DRY HEAT

Wood	Heating period Hours	Residual resistance after heating		
		212° F. Percent	300° F. Percent	350° F. Percent
Alaska-cedar	1	--	100	97
	48	95	85	85
Angelique	1	Not tested, but by inference from the wet-heat results the dry-heat values would be 98 or higher		
	48			
Atlantic white-cedar	1	95	94	--
	48	94	--	--
Baldcypress	1	96	99	--
	48	99	--	--
Douglas-fir	1	--	100	104[1]
	48	99	100	107[1]
Mahogany (true)	1	90	95	95
	48	93	87	104[1]
Redwood	1	95	97	--
	48	94	--	--
Western redcedar	1	95	93	--
	48	94	--	--
White oak	1	98	99	--
	48	99	116[1]	--

[1]Values greater than 100 reflect experimental error, not actual increases in resistance.

IV to drop no more than about one-half class in resistance below the level reached after 24 hours.

Heating at 225° F. for 1 or 24 hours seems to have altered the classes of resistance little more than the corresponding heating at 212° F. A 48-hour period of heating, however, caused a slightly greater reduction in class at 225° F. than at 212° F. At 300° F., applied for 1 hour, only the angelique, the single representative of group I, maintained its original resistance classification. Five of the other nine woods, including the group II woods, baldcypress and Douglas-fir, which had not been affected by the lesser heating, were made one class less resistant than normal, and the western redcedar, Alaska-cedar, and redwood were made one and a half to two classes less resistant. It is interesting to note that only the redwood seems to have suffered no further loss in resistance beyond the relatively large amount incurred at 212° F.

Comparison with Past Results of Heat Studies

There have been a number of earlier studies of heat effects on the decay resistance of wood, but none so comprehensive as those here reported. The observations drawn from the earlier studies, where comparable, were in general agreement with those reported here.

Boyce (2) found that dry heat at 212° F. or steam heat at 250° F., applied to air-dried heartwood for 20 minutes, had no measurable effect on the decay resistance of Sitka spruce, Douglas-fir, baldcypress, or western redcedar. In a similar study of the effect of short-term heating, Chapman (5) found that the decay resistance of shortleaf pine *(Pinus taeda)* sapwood was reduced to a residual resistance of approximately 95 percent by steam heating for 30 minutes at 212° F., and to 86 percent by heating for 5 minutes at 244° F.

Scheffer (9) observed that steam heating of green post wood for as long as 8 hours at 212° F. did not noticeably affect the decay resistance of mesquite *(Prosopis juliflora* var. *velutina)* heartwood or sapwood, but it lowered slightly the resistance of both the heartwood and sapwood of Utah juniper *(Juniperus osteosperma)*. The residual resistance of the juniper heartwood to the more damaging test fungi was about 93 percent. In appraising the possibility that commercial steaming of sweetgum *(Liquidambar styraciflua)* might reduce its decay resistance, Scheffer and Lindgren (11) observed an average loss in decay resistance of the sapwood corresponding to a residual resistance of about 90 percent when the green wood was steamed for 33 hours at 155° to 160° F.

In decay tests made on beech wood steamed for 12 hours, Eeckhaut (6) obtained evidence of losses in resistance of air-dried wood but not of green wood. His findings appear to contradict the evidence uncovered in the present studies, which showed that the presence of moisture in wood favors, rather than hinders, the lowering of decay resistance by heat. It is difficult to account for this contradiction.

Buro (3) caused the decay resistance of pine sapwood and beech wood to increase in decay resistance with heating. This heating was of an extreme type, however, so that the results are not comparable with the others. The wood was heated under molten metal, and the resistance was increased at the expense of losses in wood substance of 8 to 10 percent. The same kind of result was obtained by Stamm, Burr, and Kline (15) in studies of wood heated in metal.

An additional point must be noted here about the findings of Chapman (5) and those of Scheffer and Lindgren (11). In both investigations, decay resistance was found to have been reduced by temperatures below 180° F. or by heating periods of 30 minutes or less. From the results here reported, this mild heating would not be expected to produce a measurable effect. The specimens used, however, differed; sapwood was used in the earlier studies, heartwood in those here reported. Sapwood of all species has relatively little decay resistance, and heating apparently made some of the cellulose more assimilable by fungi. In decay-resistant heartwoods, a comparable effect on the cellulose would hardly be noticed because of the dominant effect of the natural preservatives in determining the decay resistance.

The relative order of susceptibility to loss of decay resistance among the different woods was broadly similar with dry and wet heating. The angelique, baldcypress, and Douglas-fir were least affected by both forms of heating. White oak was more or less intermediately affected, and the susceptibility of the mahogany, western redcedar, Atlantic white-cedar, Alaska-cedar, and redwood was increased most.

The fact that dry heat was much less deleterious to decay resistance than wet heat suggests that the effect of the heat is not primarily one of driving off volatile preservative constituents. Rather, it seems that the heat acts more to bring about a chemical change in the preservatives, which is accomplished largely in the presence of water.

It possibly is of some significance that the four woods most susceptible to loss of decay resistance were all softwood (coniferous) species. The only softwood exhibiting above-average heat tolerance was baldcypress. Three of the more susceptible softwoods were cedars, which have an aroma. Loss of the volatile materials, however, does not seem to be the chief factor involved. This conclusion is supported by the fact that redwood,

though nonaromatic, suffered the greatest losses of resistance.

Conclusions need not be particularly qualified in regard to the practical aspects of heating for the following reasons: 1) the woods were reasonably consistent in retaining most of their normal decay resistance when subjected to dry heat (Table 2); 2) the trends of resistance loss with wet heating (Figures 2 and 3) were basically similar; and 3) the woods tended to maintain essentially their normal class of decay resistance under the more moderate wet-heating schedules (Table 4).

If these data are to be appraised more closely, it should be kept in mind that none of the woods were represented by samples of a large number of trees. There was not the same number of trees, moreover, to represent each of the species which was sampled. Because of their larger numerical basis, the data for angelique, Douglas-fir, white oak, mahogany, and Alaska-cedar deserve more weight than those for the other woods.

Indicated Effects of Industrial Heating on Decay Resistance

The effect on the tested woods of heat to which wood is subjected in certain commercial processing operations or stages of manufacturing may be judged from the present data. For this purpose, the dry-heat data of Table 2 and the wet-heat data of Tables 3 and 4 especially are applicable.

With respect to both the temperatures reached and the moisture condition of the wood, an industrial heating process usually is far from uniform. In drying lumber or veneer, for example, the temperature in the wood and the moisture content vary with the stage of drying. Some assumptions as to temperature and moisture usually must be made, therefore, when appraising the influence of a particular process involving heat suspected of being severe enough to materially lower decay resistance. This is done in appraising the effects on decay resistance of temperature applications to wood described in the following typical examples.

Wet Heat: Wet heat is involved when veneer bolts are heated to prepare them for cutting. The bolts are submerged in water at 160° to 180° F. for 2 or more days. Inasmuch as decay resistance of Alaska-cedar, a group IV wood (Table 4), was little harmed by steam heating for 48 hours at 180° F., it is unlikely that heating of veneer bolts of any of the woods would be seriously detrimental.

Wet heat, of course, is also used in the steaming of boat frames to facilitate bending. A temperature of 212° F. is applied for ½ hour per inch of thickness. Bent frames have a common upper limit of thickness of about 4 inches. Such a frame, therefore, might be steamed for 2 hours. Judging from the data given in Tables 3 and 4 for 1 hour of heating at 212° F., steaming at atmospheric pressure for 2 hours might be expected to reduce significantly the decay resistance of only the woods in susceptibility groups III and IV, and perhaps then only the cedars and redwood.

Wet Heat Followed by Dry Heat: A combination of wet and dry heat is used in kiln drying. The initial heat necessarily is wet because the stock is green and the relative humidity of the drying air is kept comparatively high. In the later stages of drying, the heat is essentially dry because the lumber has lost its free water and the relative humidity is kept comparatively low. To dry 4/4 oak, an initial temperature of about 110° F. may be applied for 16 days. After the first 10 to 12 days, the humidity is gradually lowered. After the 16th day, the temperature is gradually increased to 140° F. over a period of 6 days; and finally the temperature is raised to 180° F. for 4 days. Dry heat is used the first 3 of the 4 days, then wet heat is used for conditioning the final day.

Although moderate heat is generally used in drying Douglas-fir, in some cases the schedule for 4/4 Douglas-fir Clears may be 180° F. increasing to 200° F. over a period of 90 hours, followed by conditioning at 200° F. for 4 to 10 hours. For 8/4 Douglas-fir in the upper grades, it might be 145° F. increasing to 175° F. for 192 hours, followed by conditioning at 180° F. for 10 hours. During the conditioning periods, relative humidities as high as 85 percent may be used.

In estimating the effect of such kiln drying on decay resistance, temperatures lower than 200° F. are of chief significance, since they relate to the wood while it is in a wet condition and thus is more susceptible to heat effects. Higher temperatures, if applied, are involved only after the wood

Table 3.—RESIDUAL DECAY RESISTANCE, OR PERCENT OF ORIGINAL DECAY RESISTANCE, REMAINING IN HEARTWOOD SAMPLES OF THE NINE DIFFERENT WOODS AFTER THEY WERE SUBJECTED TO VARIOUS APPLICATIONS OF WET HEAT

Wood	Heating period Hours	Residual resistance after heating							
		180° F.		212° F.		225° F.		300° F.	
		Range Percent	Average Percent	Range Percent	Average Percent	Range Percent	Average Percent	Range Percent	Average Percent
Alaska-cedar[1]	1	97-102	100	88-99	95	82-97	95	60-93	74
	24	93-100	96	80-86	83		75[2]		
	48	91-100	96	66-87	80		69[2]		
Angelique[3]	1	99-102	101	99-103	101	98-102	101	93-98	97
	24	99-102	101	98-100	100				
	48	96-103	100	94-100	99				
Atlantic white-cedar[4]	1				89				74
	48				84				
Baldcypress[4]	1				99				83
	48				95				
Douglas-fir[5]	1				99		97		82
	24				93		91		
	48				93				
Mahogany (true)[5]	1				98		96		83
	24				86		85		
	48				86				
Redwood[4]	1				91				68
	48				73				
Western redcedar[4]	1				92				80
	48				85				
White oak[1]	1	86-100	98	91-101	96	94-106	95	72-89	78
	24	95-105	98	78-106	93	(2)	90		
	48	86-103	98	84-103	90	(2)	85		

[1]Average values are estimated from smoothed curves through the plotted data (Figure 2). Each represents material from at least six trees. A total of eight to nine trees are represented in some of the values for 212°, 225°, and 300° F.
[2]Value estimated from projected curve (Figure 2).
[3]Average values represent evidence on material from six trees.
[4]Average values represent material from one tree.
[5]Average values are estimated from smoothed curves. The testing was on material from two to three trees.

Table 4.—CLASSIFICATION OF THE DIFFERENT WOODS FOR DECAY RESISTANCE FOLLOWING VARIOUS EXPOSURES TO WET HEAT[1]

Heat-susceptibility group[2] and wood species	Unheated (normal wood)	Heated to 180° F.			Heated to 212° F.			Heated to 225° F.			Heated to 300° F.
		1 hr.	24 hr.	48 hr.	1 hr.	24 hr.	48 hr.	1 hr.	24 hr.	48 hr.	1 hr.
Group I (least effect):											
Angelique	High	High	High	High	High	High	High	High	----	----	High
Group II:											
Baldcypress (second growth)	Moderate to resistant	----	----	----	Moderate to resistant	----	Moderate to resistant	----	----	----	Slight to moderate
Douglas-fir	Moderate	----	----	----	Moderate	Moderate	Moderate	Moderate	Moderate	----	Slight
Group III:											
White oak	Resistant	Resistant	Resistant	Resistant	Resistant	Moderate to resistant	Moderate to resistant	Resistant	Moderate to resistant	Moderate	Moderate
Mahogany (true)	Resistant	----	----	----	Resistant	Moderate	Moderate	Resistant	Moderate	----	Moderate
Western redcedar	High	----	----	----	Resistant	Resistant	Resistant	----	----	----	Moderate to resistant
Group IV:											
Atlantic white-cedar	Resistant	----	----	----	Moderate to resistant	----	Moderate	----	----	----	Moderate
Alaska-cedar	High	High	High	High	Resistant to high	Resistant	Moderate to resistant	Resistant to high	Moderate	Moderate	Moderate
Redwood	High	----	----	----	Resistant	----	Moderate	----	----	----	Moderate

[1] Classes assigned according to an established scheme of classification, based on laboratory testing, as described in the text.
[2] Groups according to Figure 4.

has dried to a point where the subsequent heating environment is dry. The fact that the woods subjected to 48 hours of wet heat at 180° F. retained no less than 96 percent of their original decay resistance (Table 3), even in the case of Alaska-cedar, a representative of group IV, makes it seem likely that most woods would tolerate the same heating fully as well.

This indirect evidence as to the effect of 180° F. and actual data on the effect of 212° F. on Douglas-fir (Tables 3 and 4), indicate that the foregoing kiln schedule for 4/4 stock of this wood (180° F. progressing to 200° F. in 90 hours) will not significantly affect its decay resistance. It could hardly be expected, moreover, that the schedule for the 8/4 Douglas-fir would affect its resistance consequentially. Although this schedule is considerably longer (drying phase, 192 hours), the initial temperatures are much milder (145° to 175° F.). For the same reason, it is even less likely that the oak would be much affected by the kiln schedule described for it (principal drying temperature 110° F.).

Results of decay tests made on Douglas-fir heartwood stock that was kiln dried corroborate the foregoing conclusions. Little or no loss of resistance to decay by *Lenzites trabea* was indicated for stock dried at 120° F. for 159 hours, 150° F. for 137 hours, 153° F. for 260 hours, or 180° F. for 65 hours. At higher temperatures, drops in resistance were indicated as follows: 202° F. for 164 hours, residual resistance 87 percent; 210° F. for 51 hours, residual resistance 96 percent, and for 98 hours, 94 percent. These higher temperatures are considerably above the principal ones usually used in drying Douglas-fir. Judging from the results of laboratory heating and the results of the actual kiln heating, therefore, it appears unlikely that the decay resistance of Douglas-fir would be affected by ordinary kiln drying.

A combination of wet and dry heat also is used in veneer drying. A common drying schedule consists of 300° to 325° F. for 20 minutes. For approximately half of this time the veneer contains free water and the wood temperature remains at 212° F. Through the remaining time, in which the high temperatures are developed, the wood is exposed to essentially dry heat. Inasmuch as the total time of heating is only about 20 minutes, and particularly since the temperature of the wet phase is only 212° F., such veneer drying could hardly affect the decay resistance of even a group IV wood significantly.

Dry Heat: Dry heat is brought to bear on wood in the course of hot-press gluing. A typical plywood schedule is 300° to 325° F. for 5 to 15 minutes. In laminating 4- by 4-inch boat frames, a common schedule is 150° F. for 5 to 15 minutes, and one for 12- by 14-inch frames is 150° F. for 36 hours. Juding from the information on the effects of dry heat given in Table 2, gluing with these combinations of temperatures and times would have little effect on the resistance of any of the woods.

Dry heat is also used in bag molding, and a common schedule is 275° F. for 20 to 30 minutes. As with hot-press gluing, such heating is not severe enough to effect a material change in decay resistance.

Literature Cited

1. American Society for Testing Materials. 1956. Tentative method of testing wood preservatives by laboratory soil-block cultures. American Society for Testing Materials Designation D1413–56T.
2. Boyce, J. S. Jr. 1950. The effect of some physical sterilizing methods on the natural decay resistance of small blocks in laboratory tests. Jour. of Forestry 48(1):10.
3. Buro, A. 1954. The effect of heat treatment on the fungus resistance and beech. Holz als Roh-und Werkstoff 12(8):297–304.
4. Campbell, R. W. and Clark, Joe. 1960. Decay resistance of baldcypress heartwood. Forest Prod. Jour. 10(5):250–253.
5. Chapman, A. D. 1933. Effect of steam sterilization on susceptibility of wood to blue staining and wood-destroying fungi. Jour. Agr. Res. 47(6):369–374.
6. Eeckhaut, L. E. 1952. Wordt de durzaamheid van het haut door det Stomen vermiderd. (Is the durability of wood decreased by heating?) Meded Lab. Hauttechnol, Geut. 10(5).
7. Englerth, G. H. and Scheffer, T. C. 1954. Tests of decay resistance of four western pole species. U. S. Forest Products Laboratory Report No. 2006, 8 pp. illus.
8. Moses, C. S. 1955. Laboratory decay test of some commercial species of mahogany. Forest Products Journal 5(2): 149–152.
9. Scheffer, T. C. 1950. Decay resistance of heating and unheated mesquit and Utah juniper post wood. U. S. Dept. Agr. Forest Pathology Special Release No. 34, 6 pp.
10. ————. 1957. Decay resistance of western redcedar. Jour. of Forestry 55(6):434–442.
11. Scheffer, T. C. and Lindgren, R. M. 1936. The effect of steaming on the durability of unseasoned sap-gum lumber. Jour. of Forestry 34(2):147–153.
12. Scheffer, T. C. and Englerth, G. H. 1952. Decay resistance of second-growth Douglas-fir. Jour. of Forestry 50(6): 439–442.
13. Scheffer, T. C., Englerth, G. H., and Duncan, C. G. 1949. Decay resistance of seven native oaks. Jour. Agr. Research 78(5 and 6):129–152.
14. Stamm, A. J., Burr, H. K., and Kline, A. A. 1955. Heat-stabilized wood (Staybwood). U. S. Forest Products Laboratory Report No. 1621, 8 pp.

WOOD—PROPERTIES AND UTILIZATION

Correns, Erich. On abnormal wood fibers. Paperi ja Puu 43, no. 2: 47–8, 50–4, 58–60, 62 (Feb., 1961). [Ger.; Engl. sum.]

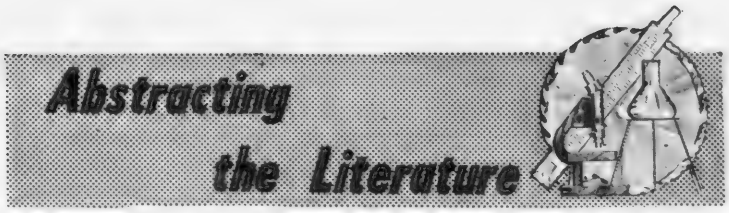
The morphol. and chem. props. of reaction wood (softwood compression wood and hardwood tension wood) are revd., and their influence on the prodn. and processing of pulp is discussed. Physiol. problems of the origin and growth of these abnormal wood-fiber cells are outlined, and expts. to elucidate the synt. mechanism of tension-wood cells are indicated. The spontaneous inhibition of lignin biosynt. in tension wood is shown to be connected with accelerated cell growth and to occur at the very start of lignification, thereby saving the plant further steps on the path to lignin formation. 16 ref.

Dadswell, H. E., Fielding, J. M., Nicholls, J. W. P., and Brown, A. G. Tree-to-tree variations and the gross heritability of wood characteristics of *Pinus radiata*. Tappi 44, no. 3: 174–9 (March, 1961).

A preliminary account is given of studies being conducted on variations in wood characs. of *Pinus radiata* D. Don. Topics discussed are: the gross heritability of percentage late wood, basic d., tracheid length, longitudinal shrinkage, spiral grain, percentage cellulose, and ring width. Estimates of correlations between certain of these characs. are also given. The estimates of gross heritability and of the correlations were made on samples from a clonal plantation: in addn., estimates are given of the gross heritability of four of the characs. by a method using both clonal and seedling trees. In the matl. concerned, gross heritability of percentage late wood, basic d., and tracheid length was found to be rel. high, that of percentage cellulose, low. The investigations are to be continued using matl. from clonal plantations and seedling progency tests. 23 ref.

Kennedy, R. W. Variation and periodicity of summerwood in some second-growth Douglas-fir. Tappi 44, no. 3: 161–6 (March, 1961).

Summerwood percentages and amts. were found to vary widely among trees and years. The variation among years was related significantly to rainfall, whereas the differences between individuals were attributed to heredity or microsite conditions. Highest summerwood percentages were found in those individual trees having the longest periods available for summerwood formation. The physiol. mechanism of springwood-summerwood transition is discussed briefly. 13 ref.



CHIP STORAGE

Rothrock, C. W., Jr., Smith, W. R., and Lindgren, R. M. The effects of outside storage on slash pine chips in the South. Tappi 44, No. 1: 65–73 (Jan., 1961).

Potential advantages to be gained in outside storage of wood chips include better wood measurement, lower handling costs, stabilized chipping and wood-yard operation and solution of storage problems arising from increased use of sawmill residues, mixed sp., and establishment of chip mills at the wood source. A test-pile, contg. 106 units of slash pine chips, was constructed in June, 1959, at Fargo, Ga. Monthly samples were collected for moisture and sp. gr. detns. and for identification of decay organisms. Samples were also collected for pulping evalns. Temps. within the pile increased as much as 60° F. in the first weeks and remained above ambient levels. A drying cycle in the pile was followed by an increase in moisture to an abnormal level. Dark staining of the chips became evident after two months' storage and was prevalent in about 50% of the chips after 5 months. Dark-stained wood showed a soft-rot type of fungus attack. Sp. gr. losses amounted to 1–1.5% per month, no greater than observed losses on roundwood. There was no loss in percentage yield nor change in permanganate no. with storage time, but the percentage of rejects decreased. Loss in pulp tear strength amounted to about 5% per month, comparable to roundwood. The results indicate that outside storage of chips in the South is feasible. 11 ref.

Klauditz, W., Ulbricht, H. J., Kratz, W., and Buro, A. Production and properties of wood-chip materials with oriented strength. Holz. Roh- u. Werkstoff 18, no. 10: 377–85 (Oct., 1960). [Ger.; Engl. sum.]

Wood-particle boards of oriented strength props. (double the bending strength of isotropic particle boards) were produced by a mech. and by the electrostatic process of orienting thin wafers in a preferred direction, followed by gluing and pressing of the overlapping chips. The dependence of board bending strength on the d. of wood sp. used was confirmed for gabun (*Aucoumea klaineana* Pierre), limba (*Terminalia superba* Engl. et Diels), and red beech (*Fagus sylvatica*). Other props. of oriented particle boards (tensile strength, swelling, etc.) were also studied. 14 ref.

Diehl, William F., Jr. Is outside chip storage practical in the South? Pulp & Paper 34, no. 11: 111–14 (Oct., 1960).

In order to provide data for detg. the feasibility of outside storage of chips in the South, a test pile of pine chips was established at St. Regis Paper Co.'s forest sta. at Fargo, Ga. Kraft pulping tests were carried out on samples from the pile at one month intervals up to a max. storage time of five months. With the exception of samples pulped at the end of the second month, the total yield was uninfluenced over the five month period. Screened rejects were lower than control samples, giving a higher screened yield. Tensile and mullen strengths were unaffected by the storage. whereas tear strength progressively decreased. This loss in tear strength, however, agrees with the reptd. results of the effects of the storage of pulpwood. Fungal infection of the chips appeared after the first month, but it is believed this can be controlled. The over-all results indicate that pulps from chips stored outdoors are as good as pulps from roundwood. Because of the various handling, procurement, and mensuration advantages involved in the outside storage of chips, the tests seem to favor the outside chip storage method.

SOURCES OF FPRS ABSTRACTS

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the *JOURNAL* the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information cannot be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry. Photostats and/or translations are available at reasonable cost from the Institute.

ABSTRACTS CONT.

FLAME RESISTANCE

Abe, Hiroshi, Onuma, Kamoya, and Fukui, Yasuo. Testing the flame resistance of wood-base materials. Bull. Fire Prevention Soc. Japan 9, no. 1: 18–22 (1959); Referat. Zhur., Khim. no. 21: 436 (1960). [Jap.; Engl. sum. Abstr. only available]

Samples of plywood, hardboard, and imsulating board were trd. with various com. flameproofing agents, conditioned to a moisture content of 5–7% (at 40° C. and a R.H. of 35%), and tested for their flame resistance and moisture-absorbing capacity. The com. flameproofing agents generally imparted a satisfactory flame resistance to the matls. tested, but increased their moisture absorptivity. The degree of flame resistance was evald. by measuring the charred surface area as a function of flaming time.

PULPING

Runkel, Roland. Semichemical processes; a brief survey of their present status. Wochbl. Papierfabrik. 89, no. 3: 97–100 (Feb. 15, 1961). [Ger.]

In an attempt to clarify the existing confusion in nomenclature of so-called "semichem." or "mechanochem." pulping processes, the author classifies processes intermediate between purely chem. and purely mech. into 8 groups, indicating the fibrous and chem. raw matls. used, pulping conditions, and yields and applns. of the pulps produced. The term "semichem. pulp" is reserved for pulps produced in 65–75% yield by cooking at 170–185° C. with sodium sulfite plus bicarbonate, carbonate, or sodium hydroxide. It is distinguished on one hand from high-yield conventional pulps (60–65% yield) cooked under pressure above 100° under mild conditions, using calcium or magnesium bisulfite (Magnefite) plus sulfur dioxide, and on the other hand from "chemimech. pulps." The latter include 5 types viz., chemigroundwood (80-90%), low-temp. NSSC or neut. sulfite (80–95%), cold (20–25°) caustic soda (88–92%), caustic soda without pressure at 60–100° (82–85%), and mechanochem. caustic soda at 80° (80–88% yield). Two-stage acid-alk. pulping with sodium bissulfite at 114° and sodium bicarbonate at 100° (80–81% yield) stands between chemimech. and semichem. processes. 26 ref.

ANATOMY

Smith, Diana M., and Wilsie, Mary C. Some anatomical responses of loblolly pine to soil-water deficiencies. Tappi 44, no. 3: 179–85 (March, 1961).

Three 17-year old loblolly pines from a good site at Crossett, Ark., were investigated at the midpoint of each annual height increment. A basipetal interaction was observed between the anatomical features studied and the June-October soil water deficits. Years of low water deficits were characd. by low percentages of summerwood at the apex and high percentages at the base of the corresponding increments; as water deficits increased this trend became less pronounced and in the year of severe drought it was actually reversed. The width of the summerwood zone, the radial counts and widths of the summerwood tracheids, and the sp. gr. of the annual increments showed similar trends. The width of the annual increments at all heights in the trees, however, was negatively correlated with soil-water deficits such that the greater the deficit the narrower the ring. 29 ref.

Peterson, R. W. The dielectric properties of wood. Ottawa, Can. Dept. Northern Affairs and Natl. Resources, Forest Prods. Labs. [Tech. Note no. 16] 1960. 22 p.

The existence of a distinct pos. relationship between the dielec. const. and the d. of wood, regardless of sp., was confirmed. For o.d. wood, the relationship is a straight line; at various moisture contents, it is an exponential curve whose slope increases with wood d., apparently because the amt. of water/unit vol. of wood at any moisture content increases with wood d. A somewhat les pronounced pos. correlation was observed between the power factor and the d. of wood. Test samples included yellow birch, Douglas-fir, sugar maple, and white spruce.

Perem, E. The effect of compression-wood on the mechanical properties of white spruce and red pine. Ottawa, Can. Dept. Northern Affairs and Natl. Resources, Forest Prods. Labs. [Tech. Note no. 13] 1960. 22 p.

Differences and similarities between normal and compression wood of *Pinus resinosa* and *Picea glauca* in the green and a.d. conditions are described with regard to max. crushing strength, max. bending strength, and toughness. In some respects the compression wood was inferior, in others superior to normal wood. 8 ref.

CHEMISTRY

Mabuni, C. T., and Unrau, A. M. The chemical composition and some physical properties of Hawaian forest woods. Tappi 44, no. 3: 227–9 (March, 1961).

The cpn. of recommended sp. for forest planting in Hawaii was detd. using gen. recommended procedures. The anal. results obtained were compared with those obtained for wood samples of Douglas-fir which originated from the Pacific Northwest. The extvs. and hemicellulose content of Norfolk Island pine (*Araucaria excelsa*), loblolly, and slash pines were gen. low in comparison to the values obtained for other tropical trees. Loblolly and slash pine contained 49% α-cellulose compared to 50% for Douglas-fir. Norfolk Island pine contained 45% α-cellulose while other species investigated contained only 34 to 42%. The D.P. of the α-cellulose from loblolly and slash pine was found to be 550 and 530, resp.; whereas the D.P. of the cellulose from Norfolk Island pine was 430. The α-cellulose prepd. from wood of Douglas-fir had a D.P. of 520. Norfolk Island pine had a higher lignin content (31%) than did loblolly and slash pine and Douglas-fir (25–27%). The d. of Norfolk Island pine and loblolly and slash pine was 0.51 g./cc. or less, whereas one of the eucalyptus sp. was heavier than water with a d. of 1.05 g./cc. 15 ref.

STRUCTURE

Rodriguez, Elvira Maria. Comparative study of the wood structure of Oregon pine (*Pseudotsuga menziesii*) (Mirb.) Franco Rev. invest. forestales (Buenos Aires) 2, no. 1: 89–99 + 1 plate (1960). [Span.; Engl. sum.]

Samples of Douglas-fir (Oregon pine) from North Am. and Argentina were compared with regard to morphol. features of the xylem. The more rapid growth of the Argent. trees accounted for the greater softness and porosity and lower d. of the wood. Growth rings were 8-13 mm. wide in the Argent. samples, as compared with 5–6 mm. for North Am. Coastal and 1–2 mm. for Rocky Mountain samples. Tracheids of North Am. samples were fewer in no./sq. mm. but had bigger radial diams. and thicker cell walls, thus accounting for the heavier wood, whereas the thinner cell walls of the Argent. samples explained the greater plasticity of the fibers. 12 ref.

NAMES in the NEWS

Edward C. Koch has been appointed a vice president of the Orangeburg Manufacturing Company, New York, division of the Flintkote Company. He will be in charge of sales for Orangeburg's asbestos-cement pipe products, which will be produced in a new $10 million plant to be built at Ravenna, Ohio.

William G. Ingram has been appointed sales representative for the complete line of National Casein woodworking glues and wood preservatives in the states of Georgia, Alabama, and Florida. Mr. Ingram has had wide experience in the woodworking field, and was formerly associated with the Peter Cooper Corporation.

Robert L. Connelly has been elected as executive vice president and treasurer of Drexel Enterprises, Inc. He was formerly a vice president and treasurer of Drexel Enterprises, and executive vice president and treasurer of the Drexel Furniture Company division.

Norman Tower, president of Midwest Finishing Systems, Greensburg, Ind., has been appointed factory representative for the Indiana territory, it was announced by the driQuik Division of the Dry Clime Lamp Corp., also of Greensburg, Ind. The appointment of **Jack L. Goodman** as assistant sales manager has also been announced by the Dry Clime Corporation.

George M. DeVere has become field representative in Texas and Oklahoma for the Protection Products Manufacturing Company, Kalamazoo, Michigan. He has spent more than 10 years in the building industry.

Thomas F. Devine has been appointed district manager for Southern Ohio, Eastern Kentucky, and Southwest Virginia for the tools and equipment division of the Owatonna Tool Company, Owatonna, Minn. Mr. Devine was previously associated with the Commercial Solvents Corporation as a sales representative.

Edward E. Tschantz has been appointed to the newly created position of chief engineer of the Fastener Division, United Shoe Machinery Corporation. Mr. Tschantz will be located in United's Shelton, Conn., plant, where activities of the division are centered.

Jeter S. Oakley has been named a special assistant to the president of Drexel Furniture Company. He has been eastern regional sales manager since 1955.

William E. Driscoll has been appointed Midwest District sales manager of the Polyco Monomer Department of the Borden Chemical Company. He joined Borden as a salesman in 1956.

Melvin C. Meyers has been named South Bend, Ind., branch manager for U. S. Plywood. He was previously a branch manager at Decatur, Ill.

Henry A. Huber, former Dow Chemical Co. technologist, has joined the E. L. Bruce Co. research staff. At Bruce, he will help conduct research on wood, wood treatment and termite control. Mr. Huber earned his Master of Science Degree at the University of Michigan in 1955, and afterwards attended the Timber Engineering Laboratory, Washington, D. C., on a scholarship.

Robert C. Harnden has been named president and general manager of Chapman Chemical Company. He succeeds **A. Dale Chapman,** founder of the 28-year old company, who moves up to chairman of the board. Mr. Harnden has been executive vice president of the company since December, 1959.

Two specialists, **H. John Ballo,** a chemical engineer, and **Roland A. Haertl,** a research engineer have been added to the research staff of the Central Research Laboratory, of the Georgia-Pacific Corporation located at Beaverton, Oregon.

Dr. John H. Ohman, forest pathologist, has been appointed to the staff of the U. S. Lake States Forest Experiment Station. He will undertake research on the diseases of northern hardwoods.

William Ferrary has been appointed sales promotion manager of United States Plywood's northeast division. He was formerly a branch sales manager in Newark, N. J.

Professor Robert W. Wellwood has been appointed Acting Dean of the Faculty of Forestry, The University of British Columbia, Vancouver, B. C. Professor Wellwood is the International Editor for the *Forest Products Journal.*

P. M. Opsal, secretary-treasurer of the Rocky Mountain Section resigned from Colorado State University to form Jason Associates. The firm will serve utility pole users with field inspectors, laboratory assay, pole records and maintenance programming.

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E–430—Mechanical engineer with 5 years or more experience in mill operations and plant quality control wanted to assist in production problems, design and planning improvements. Prefer man with Southern background. Louisiana location in small town. Plant consists of sawmill planer, kilns, furniture dimension units.

E-431—Product development engineer with experience in compression molding and particleboard research and development wanted. Replies will be kept in strict confidence. Salary in line with experience. (Oct. and Nov.)

Employment Wanted

651—Seeks employment in research, development, liaison, industry education, or public relations. Has M.S. degree, chemical research experience. Also experience in northeast state-supported agency advising industry, organizing industry education meetings, writing for wood industry, speaking, development work on bark.

653—B.S. in Industrial Wood Technology, University of Michigan, Aug. 1961. Wants to work on production control, motion-time studies, quality control and other production problems. (Sept. and Oct.)

654—Graduate of the New York State College of Forestry with B.S. in Wood Products Engineering. Eight years experience with a leading hardwood plywood company in quality control and technical engineering. Desires like position. Well trained in all phases of plywood manufacture. Age 37, stable, mature personality. (Sept. and Oct.)

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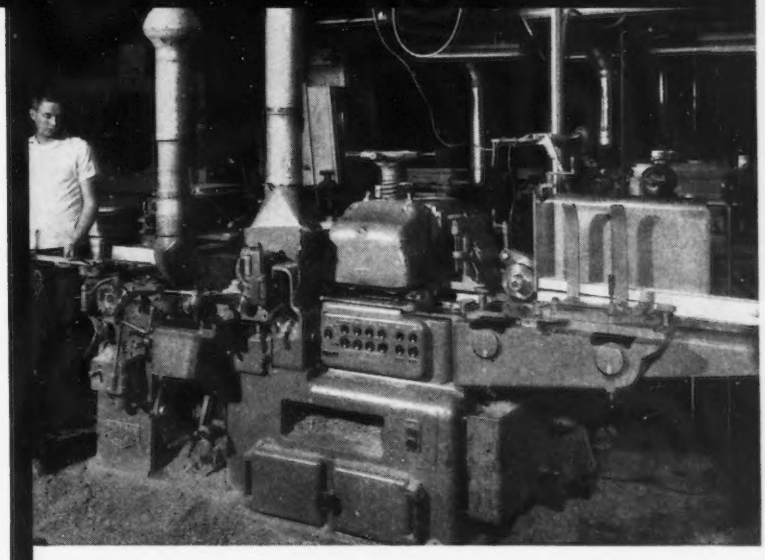

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